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THE INFLUENCE OF DIVERTING STIMULI DURING DELAYED REACTION IN DOGS

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INTRODUCTION

The experiments recorded below were undertaken to determine the effect of various diverting stimuli applied during "Delayed Reaction" in Dogs. The diverting conditions were either employed in connection with the primary stimulus, or were interposed during the delay period. While the diverting conditions disturbed the "Orientation Clues" to which Hunter (13) has attached much importance, at the same time they may be used to determine the power of the dog to retain the original stimulus under complex conditions, resembling those which prevail in natural behavior.

The observations were carried on during the year 1913-14, at the Zoological Laboratory of Northwestern University under the direction of Dr. E. H. Harper, to whom the writer expresses his thanks for assistance, suggestion and criticism of the manuscript.

DESCRIPTION OF THE DOGS: THEIR TRAITS AND NATURAL CAPACITIES

The dogs were brother and sister of a litter of four, the results of mating an English bulldog and a Scotch Collie mother. Both had the brown coats and white vests of shaggy hair that is characteristic of the Collie, and the male was a collie in build, while the female had the short bowed legs of the bulldog. The female was fawning and easily diverted. Her attention was mainly towards the experimenters, and rarely towards the pro-

blem, unless the experimenter was entirely concealed. This disposition was not conducive to the giving of good attention, and, as her seemingly dainty appetite caused the "hunger stimulus" to lose its potency, her attention was so poor that results from only the simplest associations could be obtained. The male was affectionate, but never fawning and, as the "hunger stimulus" was very strong in his case, his attention was very good in the more complex problems as well as in the simpler ones. For these reasons the results set forth in this paper are based almost entirely on the records obtained from the male.

The native disposition of the dogs was to shrink from the electric light bulbs employed in the experiments, and only long training would lead them to overcome this aversion to any place thus indicated. The artificiality of the light stimulus is unquestioned, and to react to it, the native fear of the dog must be overcome. For this reason reaction to light stimuli cannot, as some experimenters have claimed, be taken as indicating the true native capacity of the dog. It seems more logical to conclude that only the reactions to stimuli that are naturally attractive to the dog can be taken as true indices of its native capacity.

The health of the dogs during the whole period of the experiments was good. Occasionally slight indispositions were shown. The dogs were kept out of doors, and were allowed to run with other dogs and play with the children of their owner. This life prevented the acquisition of any characteristics peculiar to housed animals.

DESCRIPTION OF APPARATUS AND METHODS OF THE EXPERIMENTS

The experiments were given in a room that was kept partially darkened in order to have the light stimuli in a strong contrast to the general lighting of the room.

The apparatus is illustrated in Fig. 1.

The release box ("B") was thirty inches wide and forty inches high with a glass top measuring fourteen by fourteen inches. The door, made of wire screening, occupied the whole of one side, hinged at the top and provided with a counterpoise which enabled it to swing easily. The box could be rotated very easily on its "domes of silence." This release box stood

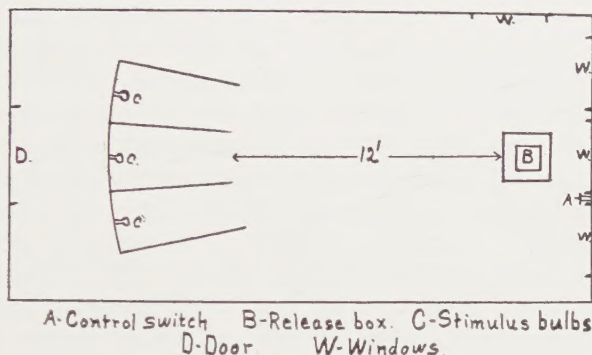


FIGURE 1

twelve feet from the mouths of the food compartments, arranged so that the mouth of each was an equal distance from the release box. The compartments were five feet deep and two feet wide and contained the food bowls. These bowls, during the latter portion of the experiments, were kept filled with water, so that the dog never suffered from thirst. The compartments were at first of wire screening (two inch mesh), but in the four light experiments the walls were made of muslin. In the two and three light experiments the lights were placed at the rear end of the compartments, but in the four light experiments they were placed over the entrances. This gave an equal stimulus from each compartment, keeping them all on a level. The fourth compartment had the approach to the food bowl of a fourteen inch board with cleats nailed to it, set up at a 30 degrees angle, and leading to the food bowl on a platform thirty inches from the floor.

The method of the experiments was at first to put the food in the bowl, switch on the light for five seconds and then off again and release the dog at the end of the delay period. Later the method omitted the placing of the food in the bowls. At first two observers were always in the room standing behind the release box so as not to be visible to the dog during his trip to the food compartment. While one handled the apparatus, the other gave the reward and kept the records. In the early tests, the food was placed in a covered bowl in one compartment, the bowls in the other compartments having been smeared with the food to avoid a special olfactory cue to the correct compart-

ment. Later this method was dropped to avoid giving visual or olfactory cues as to the position of the reward. The food was now thrown to the dog after the completion of the correct reaction, but the dog developed a lax habit of only partially completing a reaction. He would approach only to the entrance of the food compartment and then await the reward. To avoid this result a new method of giving the food reward was introduced. One experimenter stood outside of the door (D—Fig. 1) watching the dog's actions through a peephole and entered the room with the reward only after the animal had traversed the entire length of the correct food compartment.

The experiments were given under varying conditions and the results are recorded separately for each type under the following heads:

Condition "A"—Light Stimulus—Operator in view of dog. Release box faced compartments all the time. Used in the training experiments with Two and Three Lights.

"A1"—Food placed in the compartment at the beginning of the trial.

"A2"—Food thrown to compartment after a correct reaction.

Condition "B"—Operators out of sight of dog until after reaction was complete. Release box faced the compartments during stimulus and delay periods. Used in delay experiments with Two and Three Lights.

"B1"—Food placed in compartment at outset of trial.

"B2"—Food thrown to compartment after a correct reaction.

Condition "C"—Light Stimulus—Operator out of sight of dog until after reaction was complete. Release box turned 90 degrees during delay period. Used in "Two, Three and Four Light Experiments."

"C1"—Food placed in compartment at outset of trial.

"C2"—Food thrown to compartment after correct reaction.

"C3"—Operator out of room until reaction is complete. Food given after correct reaction.

Condition "AD"—Used in "Two Light" experiments. Disturbing stimuli (Olfactory, Auditory and Visual) given during delay period. Release box faced compartments during entire reaction. Food given after correct reaction.

Condition "CD"—Used in "Two Light" experiments. Disturbing stimuli (Olfactory, Auditory and Visual) given during

delay period. Release box turned 90 degrees during delay period. Food given after correct reaction.

In the early experiments the order of trials was prearranged, and followed strictly during the trials. However, in the later trials a given experiment was repeated as many times as necessary to secure a successful reaction. Otherwise the prearranged order was followed out. Care was taken that the order of trials should not be such that a possible rhythm could be followed. Record of attention to the stimulus was noted by means of watching the dog through the glass top of the release box.

Any particular orientation during the delay period was watched for and noted. The path to the food compartment was recorded and hesitations or wide turns were especially noted.

The designation "Two Light," "Three Light" and "Four Light" experiments refer to those experiments in which the stimulus was given in one of the possible two, three or four compartments and the dogs were forced to discriminate the correct one of these several possibilities.

In the early experiments the trials were given in series of five and ten, and no advance was allowed until 50% of a series were correct reactions. Beginning with the "Two Light" experiments, and continuing through the rest of the work, no advance was made until at least five successive correct reactions were obtained.

At first the dog was called back to the release box after a trial, if he did not return at once of his own accord. It was noticed, however, that after a number of unsuccessful trials, the dog would refuse to leave the release box on the opening of the door. The dog at the beginning of the "Two Light" experiments returned so regularly that it was decided not to call him back anymore. After this change the dog would lie down for a minute or two, if discouraged by several unsuccessful trials, and then would return to the box with renewed energy and with his attention to the problem as keen as ever. He did not refuse to leave the release box any more after this change in the method was made.

The time of the day when the trials were made varied from 8 to 11:30 A. M. As an interesting sidelight it may be noted that the time from 10 to 11:30 A. M. was the period in which the dog was the most attentive and eager, hence giving the

best results. In considering the records, the difference in the time of day has not been considered of enough importance to be mentioned in each series of trials.

The system of retaining the stimuli at one compartment until the dog reacted towards it correctly, begun in the "Two Light" experiments, was continued in the new trials, with the "Three Lights," thus the compartment with the poorest association received the greatest number of trials. While this savored of the trial and error method, yet it was the most successful method that could be found. It was in fundamental accord with the noticed behavior of the animal in learning the association to any one bowl or food compartment. He had to learn to react to each compartment separately, and thus set up the habit of going to that one when he received the proper stimulus. This method gave immediate results as compared with the method used at first of a prearranged schedule of compartments, and no repeating on a failure. There, in the case when the cue to "number two" had been lost, it took a series of eighty-one trials, twenty-seven of which were on "number two," to regain the lost cue and respond to it ten times in succession. By this latter method the association is generally set up again within two or three trials.

The question of "Punishment and Reward" has been a very important one to observers of animal behavior in the higher forms of life. After the preliminary experiments it was decided that a punishment, after an unsuccessful reaction, other than that of losing the food was out of the question. The dog lost interest and became afraid to try for fear of punishment. That the loss of food was in itself a severely felt punishment was already shown by the sheepish action after a failure. His tail dropped between his legs and he sneaked back to the release box with his head down. It took several successful trials to entirely lose his sheepish manner.

RECORD OF EXPERIMENTS

The dogs experimented with were not entirely unfamiliar with associating the required reactions with the stimuli, for Dr. Harper had trained them somewhat along such lines in working on another problem. Thus the writer was able at once to begin with light association experiments. Dr. Harper had found that

by the use of very attractive stimuli, such as (1), the smell of meat, (2), waving a handkerchief, and (3), a whistle call, the dogs gave very close attention and could bridge delay periods of five seconds duration.

The work of the writer falls into two main heads, (1), the "Training Experiments," to establish the Light Association and (2), the trials of "Delayed Reaction."

1. TRAINING EXPERIMENTS.

These experiments were given to familiarize the dogs with the electric light as a stimulus to reaction, in addition to the ones they had already learned. This was done by combining the light stimulus with a familiar one and gradually dropping out the familiar one and leaving only the lights as a stimulus. When the dogs came to react correctly to the stimulus when it remained during the entire trial, the delay periods were introduced in which the dog was forced to make the reaction when the stimulus was absent. These trials were recorded separately from the delay trials only in the "Three Light" experiments. While some such trials were given during the "Two" and "Four Light" experiments, they were too few to be discussed under this separate head, but are mentioned at the beginning of the corresponding "Delay Experiments."

"A" A1—The series of trials of this type extended over the period between October 4th, and November 19th, 1913. The curve representing the learning period for the discrimination of the three compartments was very short and steep. By October 25th, perfect mastery was gained. The results of the series up to October 25th are as follows: 50%, 25%, 25%, 73%, 80%, 90%, 80%, 100%, 100%. Every succeeding series, totaling eighty trials, gave 100% results. As stated before, the choice of the order of the compartment to be used was determined in advance of the series and care was taken to avoid any possible simple rhythmic succession of choices.

A2—To avoid the possibility that the dog was gaining cues to the proper reaction from the olfactory stimulus of the food in the bowl, the problem was again taken up on January 12th, 1914, almost two months after the former experiments had been stopped. In these trials, the food was not given until after the reaction had correctly taken place. Four series (twenty trials) from January 12th, to February 9th, 1914, were given

and all showed 100% results, proving that the olfactory stimulus was not necessarily a factoring one. During the same time, check series were held to test the possible rhythm of the dog's choice of compartments. A series of twenty-five trials was given on No. 2 compartment, and one of ten trials on No. 1. The first series gave 80% of the results correct, and the second showed all the trials correct. These trials show that rhythm was not a factor in the dog's choice and that the errors were due to other causes. The habit of going to a different compartment for each choice was so strong that it forced the dog at first to another compartment in spite of the stimulus calling to the same compartment again. However, but five of the thirty trials were mistaken in that way. That this rhythm of going to one compartment did not form a habit was shown by the fact that a return to the discrimination of the three compartments showed no errors or even hesitations. These results show that the dog can gain perfect mastery of a problem involving the discrimination of three compartments when the light stimulus is present at the time of reaction. The fact that rhythmic and olfactory cues are not strong factors in successful reactions is also shown.

"B"—Condition "B" means the release box faced the food compartments only for the stimulus, so that the dog could not gain any possible cue from seeing the operators go to the compartment. Only trials of the "B2" type were given, the food reward being given after the reaction was completed. Seventy-one trials of this type were given preliminary to the undertaking of the "Three Light" experiments in condition "B." Thirty-nine, or 55 %, of the trials were correct reactions, and indicated enough of mastery to favor the adoption of the delay periods of the "B" type.

II. DELAY EXPERIMENTS,

"Three Light Experiments."

Condition "A"—*Light out at release.* This condition meant that the light stimulus of five seconds' duration was present up to the moment of the release. Thus the entire reaction was performed after the stimulus had been removed, but the association was forced to bridge the gap between the instant of release and the time of the choice of the compartment. As before,

the two phases, A1 and A2, depending on the manner of giving the food, were recorded separately.

A1—Ninety trials of this type, i. e. having the food placed in the compartment before reaction, were given and seventy-one were correct. These trials extended from October 18th, 1913 to November 19th, 1913, and show that practical mastery had been gained. Perfect mastery could never be attained because the factor of attention in the dog was variable and, hence, if he did not see the stimulus, at release, he was without a cue and depended on chance. In the former tests, perfect mastery was shown because the stimulus was always there and could not be missed when leaving the release box. Several series of five trials were all correct, but longer series showed at best, only 80% of the reactions as correct.

A2—In order to test the memory of the association formed, and also to avoid the possibility of olfactory stimuli from food in the compartments, trials in which the food was given after correct reactions were taken up on February 9th, 1914, and extended over to February 16th, 1914. A series of ten trials gave 80% correct reactions and showed that the association was not based on olfactory cues in any appreciable extent. The question of rhythm kept coming up as a possibility, so check trials were given on each of the three compartments to see if this change of rhythm would cause a falling off of results, and if such a falling off should come, to see if changing the rhythm was the cause. Forty trials were given on No. 1 compartment with only 50% of correct results on February 12th, 1914. This falling off in results cannot, however, be laid to the changing of the rhythm. Just previous to the trials, the dog had run into No. 1 when the light was on and had touched the hot electric bulb with his nose and received a slight burn. As a result he avoided No. 1 constantly for the first ten trials, and for five of the next ten. The last twenty trials showed fifteen correct reactions of which the last five were successive. The later mistakes were due rather to the habit of changing, than to the following of any rhythm. A check of ten trials on No. 3 compartment followed on February 14th, 1914 and 60% were successful, the last five being in succession. The four mistakes did not follow any rhythm for the dog went to No. 2 three times in succession and the fourth time to No. 1.

The order of his choices on No. 3 compartment were 1, 3, 2, 2, 2, 3, 3, 3, 3, 3. The habit of changing from one compartment to another had to be broken up before the dog would go to any one successively on the proper stimulus. A check of fifteen trials on No. 2 compartment gave 73%, or eleven of the trials as correct reactions, the last five being in succession. All of the four mistakes were on No. 2, which was the compartment on which the previous check had been held. These results show that *habit* rather than *rhythm* was the factor that governed the successes of the check trials. The total results of A2 were lower than those of A1, i. e. 60%, and 71%, but this difference was due largely to the falling off for a while on No. 1 compartment.

Two Seconds Delay.—The trials in which there were two seconds delay between turning off of the light stimulus and the release, were all of the A1 type and were not continued long because the results showed that so short a delay had no effect on the correct reactions of the dog. Thirty-three of these trials were given between October 25th and November 19th, 1913, with twenty correct, or a percentage of sixty-one. A slight improvement was noted toward the end of the series, the last ten trials giving an average of 70% of correct reactions. These results were so nearly identical with those obtained with "Light Out at Release" that it was decided to make five seconds the minimum delay length in later experiments.

Five Seconds Delay. A1—One hundred and thirty-eight trials of the type A1 were given between October 22nd and December 1st, 1913. Of these ninety-two, or a percentage of sixty-six and two thirds, resulted in correct reactions. The factor of attention cut into the number of correct reactions, but the results show that the dog could discriminate the three compartments with practical certainty after a delay period of five seconds. The best series were those on October 27th, 1913, when twenty trials showed seventeen correct reactions, the last ten being perfect, and on November 10th, 1913, when fifteen trials showed 82% successes. Here also the last ten trials were correct.

A2—To obviate olfactory stimulus, two series of ten trials each, were given January 7th and 12th, 1914, in which the food was given to the dog after successfully completing the reaction. The first ten trials gave eight correct results and the second ten, five correct reactions. The average of 65% was so near

that of the average of experiments of the A1 type that the indications of the use of olfactory cues were negative. The question of rhythm could be applied here, but no special checks were given. However, checks on the simpler type of "Light Out at Release" coming immediately after the close of these series showed no evidence of rhythmic choice. There was no reason to think that the dog adopted a rhythmic choice for a five second delay, when he did not for a shorter delay period that was being used in experiments carried on at the same time.

Ten Seconds Delay. A1—On October 27th, 1913, the series of trials with ten seconds delays under the type A1 were begun and extended to November 19th, 1913. The results of fifty trials showed only twenty-five successful reactions. This was evidently owing to the breaking down of the cues to the middle compartment, and a return to a similar type of problem was suggested. Accordingly the "Two Light" experiments were employed again to determine what length of delay might be obtained, with a view of applying the resulting training when a return of the "Three Light" experiment should be made.

A2—On January 7th, 1914, the ten second delay was again tried under the type A2, and the benefit of training on the "Two Light" tests became apparent. The first fifteen trials showed ten correct reactions, of which the first five were successful. In the next series of ten trials on January 10th, 1914, all were successful. The 80% average showed that the dog had attained practical mastery of the problem. The likelihood of rhythmic choice of compartments was prevented by choosing beforehand a certain order and following it closely. No simple rhythm could follow the picked succession, viz., 1, 2, 1, 3, 2, 2, 3, 1, 1, 3, 2, 3, 3, 2, 1.

Longer Delays.—Scattered series of trials of fifteen seconds delay, or longer, were made on days when the dogs' attention was very keen. On November 15th, 1913, five trials, Condition A1, with a fifteen second delay were all successful. On January 9th, 1914, ten trials with twenty seconds delay, Condition A2, were all successful. As the interest of the experimenters was along the line of further reducing the possible cues by which the association might be made, no further trials were given to demonstrate the mastery of longer periods of delay with such complexity of cues as Condition A1 and A2. However,

from the ease with which the dog made the reactions, the experimenters were satisfied that with the same degree of attention as then displayed, further trials would only definitely show that the dog could retain his cues to reaction over a delay period of at least twenty seconds. As later trials will show, this assumption was not unfounded.

Condition "B."—Condition "B" means that the results here were made under conditions in which the release box faced the food compartments only during the stimulus and delay periods. The dog could not see the operator adjust the lights and so could not gain any possible position cue to the right compartment from his movements. Also the possibility of smelling the food was removed, for in all the "B" trials, the food was thrown to the animal after the successful completion of the reaction.

B2—The results here embraced the following series:

Light out at release. . . .	92 trials	44 correct	48%
Five seconds delay. . . .	80 trials	48 correct	60%
Ten seconds delay. . . .	25 trials	11 correct	44%
Fifteen seconds delay. . .	14 trials	6 correct	45%

These results are not high but nearly all well above a chance percentage of successful reactions. The averages obtained were about the same as those of the same length of delay in the "A" types and the differences are too slight to be explained on any ground, but that of the attention of the dog, which varied with his physical and psychical state. It was noticed that the middle compartment seemed to be discriminated more correctly than the other two, so check experiments were given in the "Out at Release" to see if this was really so. On No. 1 compartment, seventeen trials gave six correct reactions, or a percentage of 35. Compartment No. 2 gave seven out of ten, or an average of 70%, while No. 3 compartment showed only thirteen out of forty-five trials correct. This last result confirmed the conclusion that the cues to No. 3 were weak and that more training was necessary before correct discrimination could be shown.

Close observation of the behavior of the dog showed that he avoided the right side of the room on which No. 3 compartment was situated because of the intensity of the light. Finally he

refused to go there entirely. Of forty-five trials he reacted correctly in only thirteen, or a percentage of twenty-nine. In the last third of the trials he even refused to leave the release box, refusing twelve of the last fifteen chances. A dimmer light was put in No. 3 compartment and the next day the dog, working up from a "Light Constant" position gave 44%, or twelve correct out of twenty-seven trials. This was as good an average as he had before reached. With ten seconds delay he gave 44%, or eleven correct out of twenty-five trials. In both series the dog still avoided No. 3 compartment so another check of ten trials was given on it, with none of them successful. In the last three trials the dog refused to leave the box. When a trial on No. 1 was given, however, he left the box and reacted correctly. Further trials, with only compartments No. 1 and No. 3 in use, overcame the aversion to No. 3 and when the three compartments were again used, the reactions were as good towards it as towards either of the other two, viz.

Five seconds delay.....	67 trials	46 correct	68-3/5%
No. 1.....	16 trials	12 correct	75%
No. 2.....	27 trials	18 correct	66-2/3%
No. 3.....	24 trials	16 correct	66-2/3%

Condition "C." The experiments listed under condition "C" were those in which the release box was turned away from the food compartments during the delay period and in which the dog did not see the operator until after the entire reaction had been completed. The release box was turned facing the compartments just soon enough to release the dog at the end of the delay period and not allow him any time to see the compartments before he was forced to make his choice. This change of conditions was an attempt to forstall the probable chance that the dog was guided by orientation cues to a great extent and was not using memory cues. If so, and this orientation should be changed during the delay period, then he would not be able to react correctly. A minor point in regard to the effect of keeping the problem always before the dog during the delay period was also involved in the change. If this had had any effect of affording a cue to reaction, the turning of the box destroyed its function. The introducing of a new field of view during the delay that was entirely foreign to the problem was

apt to have a distracting effect on the dog's attention and thus tend to drive away the memory of the proper association. The records from these experiments were taken as satisfactory proof of the question as to whether the belief in such a probability was well founded. The release box had to be turned rather quickly in order to disturb the orientation of the dog *within* the box, as well as to disturb the entire orientation toward the food compartments. The preceding observations had borne out the statement of Hunter (13), that the dog showed orientation only by the movement of the head, and that causing the head to change its position would effectively destroy the dog's orientation. The sharp turn of the release box affected this disturbance of orientation, for the dog was forced to move the whole body in order to maintain his equilibrium. Under these new conditions, no evidence was seen of the tense, eager waiting that the dog had formerly displayed during the delay period, and the dog even used the time for scratching at fleas, and during the longer delays would close his eyes and apparently take little cat-naps while waiting. As soon, however, as he felt the release box return to the normal position, he was wide awake and eager, and hurried out of the door before it was fairly opened.

The experiments are recorded under the two heads "C1" and "C2" differing as before, in the manner of placing the food reward. The records began with the minimal delay of five seconds after a five seconds light stimulus.

Five Seconds Delay. C1—Only fifteen trials of this type were given, as evidence of a breakdown on No. 3 compartment appeared and a return to an "A" type of experiment was necessitated. The results of the fifteen trials was nine correct reactions. Of the five trials on No. 3 compartment, all were wrong. Only one of the five trials on No. 2 compartment was a wrong reaction. At this time, November 4th-8th, 1913, the aversion or loss of cues to No. 3 was noticed in all the sets of experiments then going on, and so the series of check trials described under condition "A" was given. After this series the dog regained his cues to No. 3 and went there as readily as to any other compartment.

Ten Seconds Delay. C2—On January 22nd, 1914, the "C2" experiments were taken up again after the dog had had a month and a half's training in all the conditions including "AD" and

"CD" on two compartments. Resumption of the "A" and "B" types with the three compartments had been so successful that a ten second delay was used at once on beginning the "C" trials. Here the food was thrown to the dog after completion of the correct reaction. The records obtained here show perhaps better than any others the learning curve, beginning very low and rising gradually to a practical mastery of the problem. The first twenty-five trials were very poor, only seven being correct. Of the errors, eight were because the dog refused to leave the box at the release. The dog gave no attention at all to the stimulus and when he left the box on release it was more a result of training than a reaction to a formed association. The inattention was due to the lack of hunger.

On January 24th, 1914, the dog was more alert, and tried to solve the problem but was not very successful. Out of sixty trials only twenty-seven or 45% of them were correct. This low result was due to the dog's inability to retain the associations for the discrimination of the three compartments over a delay period of ten seconds, and was not due to inattention to the stimulus.

On January 27th, 1914, twenty-five trials were given and the benefit of the previous training began to be evident, for seventeen or 68% of the trials were successful. The last nine trials were all successful.

The record of the twenty-one trials given on January 28th, 1914, were not so successful as those of the preceding day, having only eleven or 52% of the trials as correct reactions. The falling off was due to the indifference of the dog to the stimulus in the last ten trials. The average for the first eleven trials was 73% and for the last ten only 30%.

February 16th, 1914 was the next day on which the "ten second delay" trials were given, and of eighteen trials sixteen or 88% of them were correct. The last twelve trials showed perfect reactions. The records made on this date were the best obtained on the ten second delay problem, for fifteen trials on February 10th, 1914 showed eleven, or 83% of them correct.

The learning curve obtained in these trials with the ten second delay shows the growth of the power of carrying the associations over the delay period the most perfectly of any of the delay series. All show the same general results, but none show

such a smooth curve. A short summary of the data may make this growth more apparent.

"Five Seconds Light—Ten Seconds Delay."

1/22/14	25 trials	8 correct	27%	Falling off on No. 3
1/24/14	60 trials	57 correct	45%	Falling off on No. 1.
1/27/14	25 trials	17 correct	68%	Last nine correct.
1/28/14	21 trials	11 correct	52%	Refused to act seven of last eight trials.
2/ 6/14	18 trials	16 correct	88%	Last twelve correct.
2/10/14	15 trials	11 correct	73%	Trials five to eleven correct.

That the low records at the beginning of the experiment were not due to the breaking down of orientation cues, is seen by comparison of the records for trials of "Ten Seconds Delay" condition "A2" given at the same time.

On January 17th, 1914 a series of thirty "A2" trials showed only 33-1/3% or "Chance" percentage of trials correctly completed. Of the "C" trials, a series of twenty-five on January 22nd, 1914 showed only six or 27% of them as correct reactions. This shows that the lack of attention to the stimulus was the cause of the failures and that attention and training must be gained before higher results could be obtained, as the results show there was a parallel rise of the learning curve in the problem given in both the "A" and "C" conditions. The added training and the better attention given to the stimulus gained a practical mastery of the problem at the same relative time, i. e. February 5th, 1914 for trials of Condition "A2" and February 6th, 1914 for trial of Condition "C2." The daily record of January 27th, 1914 showed very nicely the typical day's work with an advancement coming at the end of the series of trials. Many of the daily records showed a higher average of results for a single series, but this example is given because it shows the growth from a very low beginning to a high ending.

Stimulus at Com- partment	3 3 3 2 1 1 1 2 3 3 2 1 3 3 3 3 2 1 3 2 2 1 2 3	25 Trials
Response at Com- partment	1 2 3 2 0 2 1 2 2 3 3 1 2 0 0 2 3 2 1 3 2 2 1 2 3	Failures mostly on No. 3 Com- partment
Correct	x x x x x x x x x x x x x x x x x	17 Correct— 68%

The rhythm for these trials was very irregular, being selected beforehand and only varied by keeping the dog at a compartment until he had gone to it correctly. Then the regular schedule was resumed. This method seemed preferable to that of keeping to the fixed schedule strictly, as it gave the dog extra practise on the compartments to which his cues seemed to be weakened.

Fifteen Seconds Delay. C2—The fifteen seconds delay type of the experiments given under condition "C2" extended over the period between January 17th, 1914 and February 12th, 1914. In all there were sixty-seven trials, and of these forty-four, or 66-2/3%, were successful reactions. The last twenty-two trials showed much improvement and gave 85% of them as correct reactions. The highest record reached on any individual day were those on February 6th and February 12th, 1914, when nine out of ten and twelve out of fourteen trials were correct. The results of the earlier series were lower and showed a decreased learning power instead of an increased one as a result of training. This decrease was due to the apparent failing of the cues to No. 3 compartment. This failing was noted in all the types of experiments going on at this time, and a special check series of twenty trials on No. 3 compartment was given to restore these cues. After regaining the cues, the records given above as the highest obtained, were the results. The reactions to the other two compartments became more accurate, due to the training, as the records show, for while at first the errors on No. 3 were only 40% of the total number of errors, they were 71% at the end, just before the check experiments were given, and the total number of errors increased only 17%. As the increase of errors on No. 3 was 74%, the difference can only mean that there was a strong decrease in the errors on the other two compartments. The summarized results for "Fifteen Seconds Delay"—"C2," are as follows:

1/17/14	17 trials	10 correct	57%	Errors equal on No. 1, No. 2, and No. 3.
1/18/14	14 trials	8 correct	57%	Falling off on No. 3.
1/20/14	14 trials	8 correct	57%	6 of the errors on No. 3.
2/ 6/14	10 trials	9 correct	90%	Last five correct—Error on No. 3.
2/12/14	14 trials	12 correct	83%	Last five correct—Errors on No. 3.

The usual methods of avoiding possibilities of rhythm were used, with the modification of keeping up the trials on one compartment until a successful reaction to it was obtained. The method of the experiment eliminated all possible olfactory orientation or position cues.

Delays Longer Than Fifteen Seconds. The records quoted above were the highest and best results obtained, for problems of the "C" types that are complete enough to be the basis of claims of mastery. However, shorter series of the longer delay periods were given, with the view of discovering as to whether the cues used could bridge delay periods of longer duration than ten seconds. On February 10th, 1914, a series of ten trials of "Twenty Seconds Delay" "C3" were given, with 90% of the reactions correct. In the case of the error, an interesting sidelight was noticed: The dog did not see the stimulus, to the knowledge of the observer who had watched the animal carefully, but seemed intent on rubbing his nose with his paw. On release he automatically hurried out until in front of the compartment toward which he had faced at release. Just at the entrance he seemed to realize that a choice was to be made and paused suddenly, then he slowly walked to each entrance in turn and looked up at the light bulb as if seeking for a cue. Then he gave up and returned to the release box without making an attempt to enter any of the compartments. What the mental attitude of the dog may have been, the writer leaves to some experienced animal psychologist to explain. On the same day, the dog gave four out of five reactions correctly on "Five Seconds Light and Thirty Seconds Delay," which on February 12th, 1914 he reacted correctly in nine out of eleven trials of the same length of delay for a percentage of eighty-three. Five trials on the fourteenth were all correct and of the whole number of thirty-one trials, twenty-seven, or 87% were successful reactions. These trials, though rather few in number showed such a constancy in the per cent of successes that the experimenters believed that strong evidence of mastery of the problem was presented.

Two series of trials of "Forty-five Seconds Delay" were given on February 14th and 16th, 1914. Ten trials on the first day showed only five correct responses and ten trials on the second showed but six correct. Of the nine errors, five were for No. 2

compartment. Only three of the light trials on No. 2 obtained correct reactions. This seemed to indicate that the cues to No. 2 were almost lost. In the "Two Light" experiments (discussed in the next section) No. 1 and No. 3 compartments had been discriminated after a delay period of much longer duration, but here the cues to each of the three compartments did not seem to be localized well enough to be differentiated after they had had the chance to become indistinct during the delay period of forty-five seconds. The cues to No. 2 had so lost their individuality during this long delay that the dog could not differentiate them from those of No. 1 and No. 3 in even a "chance" number of attempts. As a desire was felt to increase the number of discriminated objects, and not to increase the delay period on the three compartments, no more trials were given on this type of experiment.

"Two Light Experiments."

By November 19th, 1913, the experimenters saw that the dog had not received proper training to do well at the three light problems, and that success there would mean spending much longer periods of training on each phase than was at their command, so it was decided that a thorough training on the two lights would gain time and also give a test for comparison with the results of Hunter (13) on the length of delay possible to obtain with two lights. Another cause for the adoption of the two light method was the fact that the trials so far, had shown that the cues to No. 2 compartment were very weak and could easily be dropped out. The method used in the "Two Light" trials were slightly different from those in the "Three Light" types. From the beginning, the stimulus was retained at each bowl after a mistake until the dog made the correct response. He was also kept at each type until each series showed five successive correct reactions, before the difficulty of the problem was increased. These methods, it was hoped, would bring the association between stimulus and reaction to the correct compartment, much more strongly into mind. Previous training had failed to strongly set up this association. After the two light association was thoroughly

learned, the addition of a third compartment would be much simpler than trying to teach association to all three compartments at once.

The results were extremely successful from the very first, and showed practical mastery of all the phases of the "A," "B" and "C" types immediately.

"Two Light" trials were given in condition "A" of the following types, "Light Constant," "Light Out at Release," "Two Seconds Delay," "Five Seconds Delay," "Ten Seconds Delay," "Fifteen Seconds Delay" and "Sixty Seconds Delay" with the following results. All these results showed a high percentage except those on "Five Seconds Light, Fifteen Seconds Delay" when the dog was very fatigued and gave but poor attention at the beginning of the trials. In all cases each series was continued until at least five successive correct trials were made.

A short summary of the trials is as follows:

Light constant	8 trials	8 correct	100%
Light out at release	5 trials	5 correct	100%
2" delay	10 trials	9 correct	90%
2" delay	34 trials	32 correct	97%
10" delay	12 trials	11 correct	92%
15" delay	16 trials	11 correct	69%
60" delay	10 trials	8 correct	80%

The results for condition "B" which follows in summary, were not so favorable, yet results beyond that of 50% of chance were obtained in all but three series of ten each on 11/17/13, 11/19/13 and 12/16/13. On each of these three days the dog showed symptoms of indigestion. These poor days pulled down the general averages for the types in which they occur, but the other records of each corresponding type were high enough to balance up and give a safe margin over the 50% of "Chance."

5" delay	26 trials	18 correct	69%
10" delay	22 trials	14 correct	64%
15" delay	18 trials	11 correct	61%
30" delay	15 trials	10 correct	66-2/3%
60" delay	27 trials	18 correct	66-2/3%
120" delay	11 trials	8 correct	72%

The results for condition "C" were better than those of either condition "A" or "B," as a much better practical mastery of each type was shown

5" delay	35 trials	30 correct	86%
10" delay	30 trials	28 correct	93-1/3%
15" delay	15 trials	15 correct	100%
20" delay	10 trials	10 correct	100%
30" delay	38 trials	27 correct	70%
60" delay	13 trials	7 correct	54%

The results on "Sixty Seconds Delay" were but little better than chance, because of an aversion to No. 3 compartment, due primarily to a too brilliant light. When this was replaced by a dimmer light on shorter delay trials No. 3 compartment was chosen as well as No. 1.

The success of these series of trials led the experimenters to attempt various types of diversion during the delay period, first in condition "A" and then in "C." These experiments were recorded under the heads of condition "AD" and "CD" respectively.

Condition "AD"

In condition "AD," meat was held in sight of the dog during the delay and the experimenters talked and whistled to him in order to keep his attention away from the problem before him. For the first five of the seventeen trials given, the dog did not do very well, and seemed to have lost his cues, but soon regained them and the diversion seemed to have no effect on correctness of reactions, for the last nine reactions were all correctly and unhesitatingly made.

The exact record will show the effects, the best of any way.

Stimulus at Compartment	1 3 1 1 1 1 3 3 3 3 1 3 1 3 3 1 3	17 Trials
Reaction at Compartment	1 3 3 3 3 1 3 0 3 3 1 3 1 3 3 1 3	4 Errors
Correct	x x x x x x x x x x x x	13 Correct

Condition "CD."

In this condition diverting stimuli were given during the delay period of condition "C." These stimuli consisted (1)

of the sight of operator walking in front of release box, (2) the sound of the operator's voice calling the dog, and (3) a whistle call with a piece of meat hung before the door. The object was to find out if such stimuli could or would cause the dog to forget his cues to the food compartments. The dog answered each of these diversions by giving his whole attention to them, often by snapping at the meat through the screen or by getting up and turning around when called and not released.

These series of trials of this condition "CD" were given on December 8th, 1913 and December 15th, 1913 and concluded the trials on the "Two Bowl" problems. The first series on December 8th, 1913 was of Ten Seconds Delay with 100% results. Five trials of One Hundred and Twenty Seconds Delay also showed perfect reaction with no evidence of the effect of the diverting stimuli. A series of light trials on Sixty Seconds Delay followed and showed 75% of the reactions correct, the last five being perfect. As there seemed to be no sign of the dog losing his cue to either of the compartments, a sudden jump was made to a delay of five minutes, and a series of five trials showed all as perfect reactions. There was no hesitation displayed in the dog's choice of compartments, nor did there seem to be any sign of an hindering influence, due to the diverting stimuli introduced during the delay. In order to ascertain whether these results were chance, or whether they showed the power of retaining a cue powerful enough to bridge the five minute gap, and then discriminate perfectly between the two bowls, another series of trials on these long delays was held on December 15th, 1913. As usual the dog was kept at a compartment until he succeeded, and no set of trials was given up until five in succession had been correct. Beginning with a two minute delay seven trials resulted in the last six being correct (or a percentage of eighty-six.) With a three minute delay, five trials were all correct. Then a five minute delay showed seven successive correct trials. Then the next trial was unsuccessful for the dog seemed to show fatigue and during the delay period dozed in his box and did not pay attention to the attempts of the operators to attract his attention. On release he went out slowly and wandered around and finally reached the food compartments and entered the wrong one. Because of the loss of attention, no more trials were given.

No attempts at longer delays were made as no further object seemed to justify their continuance. During all these trials of the "Two Light" type, the usual method of avoiding rhythmic succession of trials was used, as well as the system of throwing the food to the dog after a correct reaction had been made. This latter method avoided the possibility of the use of the olfactory stimulus as a cue to reaction. The time gaps already bridged were too long for any sensory after image to have been retained and hence diversion stimuli would have no lasting effects on the cues by which the dog retained the association. No attempt was made to find out definitely what those cues were. The above results show that the power of discrimination of two objects, fairly well separated (six feet), was within the untrained capacity of the dog, and that the responses given after the delay periods were the result of training. This training enabled the retention of these powers of discrimination, necessarily through some process, presumably memory. The negative results gained by diverting stimuli during the delay period, show that mere physical clues or sensory after images could not suffice as cue retainers, but that there must be a definite mental process involved, that may be called "Memory Association." Since an association of stimulus and food compartment was necessary, and since correct reaction demanded that such an association be retained by some mental process, the "C" type of problems having shown the absence of the physical cues, therefore, as psychologists agree that sensory after images could not bridge a gap nearly as wide as the five minute one that this dog has done, the process must be one that involves the memory.

"Four Light Experiments."

In the middle of February, 1914, it was suggested that the problem be made more difficult by increasing the number of compartments, the cues to which must be remembered, rather than by the continued increasing of the length of delay periods over which the association cues must bridge. So to increase the number of compartments, No. 4 was added, but not on the same ground level as the other three. The food was obtained only by going up to the compartment on a board, eight feet long and having a 30 degree pitch. The light stimulus was however

at the same height from the floor as in the other three compartments. In order to quickly teach the dog the habit of going to No. 4 compartment, and to climb the inclined board without fear, the operators "put" the dog through the reaction. That is, one held a piece of meat at the top of the incline and called the dog. The other experimenter led and pushed the dog up the incline. After four trials, in which he was helped, the dog ran freely up the incline when called, without showing any signs of fear. Then three trials were given in which both light and voice were used as stimuli and the dog released immediately from the release box. Each one of these trials was successful. Next, three trials were given in which the light alone was the stimulus, it being removed as the dog was released. These three trials were all correct. From this point the regular procedure of the experiments was taken up again. Five trials of "Five Seconds Delay," position "C3" were given on February 6th, 1914 and all were correctly reacted to. On the same day series in "Ten Seconds," "Fifteen Seconds" and "Thirty Seconds Delay" were given, all in condition "C3." Of the ten seconds delay, five trials were all correct, as also were five trials of fifteen seconds delay. On February 17th, 1914 a series of nine trials of twenty seconds delay was given, of which seven or 76-2/3% were correct. The last five trials were correct. On four different days, series of trials of "Thirty Seconds Delay" were given and the record for the last day showed very great improvement, over those of the preceding ones. In the last three series, five successive correct reactions were obtained before any longer delay was attempted. The first day the dog broke down entirely on No. 3 compartment and a shorter delay had to be used. The records for the four days are as follows:

2/16/14	9 trials	4 correct	45%	
2/17/14	14 trials	9 correct	64%	Last 5 trials 100%
2/19/14	6 trials	5 correct	83%	Last 5 trials 100%
2/21/14	9 trials	8 correct	89%	Last 5 trials 100%

Encouraged by these results, on February 17th, 19th and 21st, series of trials on "Forty-five Seconds Delay" were given. On February 17th, five trials were all correct. On February 19th, the last five of seven trials were correct, giving a percentage

of seventy-one. On February 21st, twelve trials were given and of these trials 2, 4, 5, 6, 7, 8, 9, 11 and 12 were correct reactions giving a percentage of seventy-five. This series gave six successive correct reactions in trials four to nine. On the 19th, nine trials on a one minute delay were given and 66-2/3% of them were correct reactions. The last five were 100% correct.

These experiments showed that the dog was able to accurately discriminate the stimulus from four compartments, that were only two feet apart, and that he was able to retain the cues to this discrimination over a delay period of at least one minute, without showing signs of a break-down in the cues to any one of the compartments.

RESUMÉ OF RESULTS

The first conclusion drawn from the records was that perfect mastery could not be gained because of the vacillating factor of attention. This factor was high enough to give practical mastery of the problems, but failed to give perfect mastery. Sheepish behavior was apparent whenever the dog did not feel exactly right, or when he made several unsuccessful trials in succession. After such a period of failure the dog would hesitate for fear of more mistakes, and in doing so would fail to get the stimulus and make the association. This sheepish action was the cause of a large percentage of the failures to make the correct reaction. It was found, however, that allowing the dog to return to the release box at his own will did away, to a great extent, with sheepish actions. If the dog was always called back, after several failures he would become discouraged and give up trying. If he was left to his own devices, after several failures he would lie down and rest for perhaps two minutes and then return of his own free will and try over again with his attention and interest as alert as ever. No sign of sheepish behavior appeared then.

The records also show the contrast between the different parts of the experiments, i. e. the routine of leaving the release box when the door was opened, and that of making the correct reaction to the stimulus given. Often when he refused, through discouragement, to make a choice of compartments, he went through the routine part without a hitch. It was found, however, that extreme discouragement affected even the routine

part and the dog refused to even leave the release box on the opening of the door. On command the routine part would be resumed, but correct reactions, or even attempts at choosing did not follow such commands. Hunger also caused attention to vary. When very hungry, the dog was in good attention and gave good results, and vice-versa.

Another interesting factor in regard to the preference for any certain compartment was found in the records. A summary will give a better idea of this preference than can the mere description above.

TRAINING TRIALS

Condition "A"—Three Lights	101 trials	85 correct	85%
No. 1	32 trials	30 correct	94%
No. 2	34 trials	26 correct	76%
No. 3	35 trials	29 correct	83%
Condition "B"—Three Lights	81 trials	43 correct	53%
No. 1	20 trials	12 correct	60%
No. 2	33 trials	15 correct	45%
No. 3	28 trials	16 correct	57%

DELAY TRIALS

"Three Lights"

Condition "A"	381 trials	249 correct	64%
No. 1	128 trials	87 correct	68%
No. 2	132 trials	77 correct	51%
No. 3	121 trials	85 correct	71%
Condition "B"	211 trials	118 correct	56%
No. 1	68 trials	36 correct	53%
No. 2	74 trials	46 correct	62%
No. 3	69 trials	36 correct	47%
Condition "C"	310 trials	193 correct	64%
No. 1	103 trials	60 correct	59%
No. 2	107 trials	73 correct	68%
No. 3	100 trials	60 correct	60%

"Two Lights"

Condition "A"	95 trials	85 correct	89%
No. 1	46 trials	44 correct	95%
No. 3	49 trials	41 correct	84%

Condition "B"	119 trials	78 correct	65%
No. 1	53 trials	39 correct	73%
No. 3	66 trials	39 correct	59%
Condition "C"	141 trials	108 correct	76%
No. 1	69 trials	63 correct	91%
No. 3	72 trials	45 correct	62%
Condition "AD"	17 trials	13 correct	76%
No. 1	8 trials	5 correct	62%
No. 2	9 trials	8 correct	90%
Condition "CD"	51 trials	46 correct	90%
No. 1	30 trials	26 correct	87%
No. 3	21 trials	20 correct	95%

"Four Lights"

Condition "C3"	90 trials	71 correct	79%
No. 1	24 trials	21 correct	88%
No. 2	23 trials	13 correct	57%
No. 3	20 trials	16 correct	60%
No. 4	23 trials	21 correct	91%

The above summary shows that the associations toward the different compartments varied considerably. Any two of the compartments would have perfect associations while the other would be neglected. The next day the result would be vice-versa, and the neglected one would become the compartment best associated. Thus, while one day's record would show more trials at one compartment than at another, the whole series of trials showed about an equal number of trials on each one. This variation might be construed as an argument against the possession of reason by the dog. If the light always meant the compartment that contained the food in the three light trial, why did not the dog go to the light when it was placed over a fourth compartment? This presupposes that the dog had mastered the association between the light and reaction necessary to obtain the food and gave good results in the three light experiments. The fact is that he did not, of his own accord, make the new association. Evidently if reason was working here as a factor in association, seeing the light anywhere over a dish would cause a motor impulse to go to it. But, as it

did not, it is evident that reason was not the cause of the formations of the associations. That habit is the cause of association being formed is shown by the fact that after being taught to go to the extra compartment by special training, and the habit of going there firmly fixed, a series of trials including the four compartments showed that the association of stimulus and response is just as perfect for the fourth, or new one, as for any of the former three. An argument that would seem to point in just the opposite direction, tending to support the idea of the functioning of reason, is given in the actions of the dog in cases of wavering. In some cases it was noticed that the dog would start for one compartment, and then swerve, often very sharply to another, sometimes wrong and more often right. Was it reason that made the dog believe that he had made a wrong choice and caused him to change his selection, or was it the motor energy in his muscles that forced him out in whichever direction he happened to be facing when released? Was he unable to set up the motor reaction connected with going to the compartment for which he had made the association between the movement to get the food and the light stimulus until the first momentum was over? To the experimenters it seemed that the use of reason is the most feasible solution, but the psychology of such a question is left to men more trained in that line than the writer. A still more striking and less easily explained action, was manifested when on getting almost to some compartment, the dog would stop, hesitate and then go ahead or choose another compartment, sometimes wrong, sometimes right. A few times the dog gave up entirely and returned to the release box without even trying. Did the dog forget his cues, and realizing it, attempt to reason out the correct association, and on failing to do so, would return to the release box; or did he fail to get the cue and form the association, and, from habit, rushed out when the release box was opened? That is another question for the trained psychologist to answer.

In condition "A1, Three Lights" it was seen that No. 2 compartment was discriminated only 88% as well as No. 1 and No. 3. Thus it shows that while it was easy to discriminate two widely separated compartments, the addition of the one in the middle made it much more difficult to keep its cues separate from those of the other two.

In condition "B, Three Lights," it is noticed that compartments No. 2 and No. 3 are discriminated equally well and that No. 1 is the one not so well discriminated. This failure on No. 1 was due to a long period of fear of the light there, as the dog had burnt his nose on it at the beginning of the "B" trials. The equal discrimination of No. 2 and No. 3 shows that the training on No. 2 received in condition "A" had borne fruit. In condition "C—Three Lights," compartment No. 2 was discriminated 25% better than either No. 3 or No. 1. In both compartments, the dog had lost the cues to their discrimination several times and had been given special training on them. The previous training on No. 2 was shown in the results of the trials. This trial in the power of discriminating No. 2 from the others is a proof of the benefit of special training in habit formation, for the habit of going there on stimulus, had become so firmly fixed that errors became steadily less, and passed in strength, the habits that caused him to go to the others on stimulus.

In the "Two Light" experiments, condition "A," "B" and "C" show better discrimination of No. 1 than of No. 3 by about 18%. This favoritism was due to the fact that the light in No. 3 was too bright, and after changing to a dimmer one, it took over a week before the fear of No. 3 was sufficiently overcome to allow the dog to enter freely whenever the stimulus was given there. As the "Two Light" trials took place in a period of only two or three weeks, this trouble with No. 3 materially affected the general results of a large number of trials.

In the trials of condition "AD" and "CD" that took place in the period between December 12th and 15th, 1913, the results were reversed and No. 1 was the one that was not so well discriminated. In condition "AD" the difference was too small to be noticed but in condition "CD" a difference of 11% was found. This difference was due to the fact mentioned in the "Three Light" types, i. e. that the dog had burned his nose on December 15th, and hesitated to go to No. 1 after that. This set of experiments was concluded on this day and the "Three Light" type resumed, but the fear of No. 1, however, was carried over and effected the records there. In all these trials, care was taken that, while rhythmic successions of choices of compartments was avoided as much as possible, the number of chances was approximately the same for each compartment. The

usual result was that the compartment that was discriminated the least accurately received a few more trials than the others.

Another point gained from the records is that the reaction comes, not from seeing a light over a compartment and then going there when released, but from the fact that when a light was shown over a *certain* compartment to which he had been *trained* to go on stimulus, the dog went as a matter of habit. Hence, a light over a compartment to which he was not in the habit of going did not set up in the dog's mind the association of "Light—Movement to Light—Food" or for the incitations to the motor response that comes on release, that the training to that compartment would. The dog must be in the *habit*, gained through thorough training, of going to an indicated compartment on release, or he would not pay any attention to it, but on release would go to one of those to which he was accustomed to go, even though he had received no stimulus to go there. The *mechanical* is stronger than the *reasoning* in this case. Addition to the number of compartments means that the dog must have special training on the new one before it can become one of the *several* to which he is trained to go on release after a stimulus had been given.

In the "Three Light" problem, condition "A" shows that by course of long training a light stimulus can be made effective, and the dog can remember the cues formed and the associations set up by the light stimulus for the three compartments over a period of one minute delay between stimulus and release. The latter part of the records show that the olfactory stimulus to reaction was not an important factor, as the records were as good as when the presence of the food in the bowl gave the possibility of such stimulus.

The records from Condition "B" show that the sight of the operator placing the food in the bowl and operating the lights gave no cue that was necessary for correct reactions, as the general results of "B" are practically the same as those of "A" while the dog could not see the operator until after the entire reaction had been completed.

Condition "C" gives results of the effect of orientation and the retaining of the compartments in view during delay period, on the correctness of reaction. The records show that the dog

did not use orientation cues at all, or that they were of such minor importance that they were dropped without effecting his reactions. The turning of the release box during the delay, thus destroying orientation to the food compartments and the disturbing effect that a new set of objects before the sight would have, did not give records any lower than those of condition "A." In fact the records for the discrimination of the three lights was better than those of "A," and the delay period reached was of the same length in both conditions. From these results the experimenters claim that this dog should be classed with the group in which Hunter (13) places his raccoons, i. e. the group that does not depend on the retaining of orientation to give them the proper cues to obtain correct reaction.

The "Two Light" experiments show that the discrimination of two compartments is easily within the native capacity of the dog, for without previous training, once the light association is formed, he gives 100% results. Perfect mastery is here shown for all the conditions for delay periods up to one minute for "A," two minutes for "B" and one minute for "C." Condition "CD" gives results that show that diverting stimuli, such as sound, sight, smell, etc., during the delay period of condition "C," do not materially affect the power of correct discrimination of the two compartments even though the cues must be retained over a period of as long as five minutes. In none of the delays of any condition, was there any sign of breaking down in the cues to any compartment, in the longest delay periods used. No attempt was made to find the limit of the time over which the dog could retain the association cues, in any of the problems.

The "Four Light" type was tried only in condition "C" and it was found that through the benefit of previous training, the dog, after a thorough training on the new compartment, could discriminate the four compartments up to a one minute delay as well as he had the three compartments. The first trials showed, however, that without definite training, and the formation of the habit of going to compartment No. 4 on stimulus, the dog paid absolutely no attention to the extra compartment, even though the light was constant, but went to one of the compartments to which he was accustomed to go on release.

SUMMARY OF RESULTS

(1) The habit of going to a compartment on release must be formed for each one separately before discrimination of from two to four can occur.

(2) The discrimination of four compartments was retained for at least a delay period of one minute, and of a fewer number of compartments, for a much longer period.

(3) The discrimination of two objects is within the native capacity of the dog.

(4) Visual and olfactory cues are not necessary for correct reaction.

(5) Signs of orientation may be prominent in the dog, but such cues were not important for the success of the delayed reaction in the animal experimented upon.

(6) Distractions of all kinds, visual, olfactory and auditory, or such as might arise from the natural behavior of the dog, may not necessarily interfere with successful delayed reactions.

BIBLIOGRAPHY

1. AMENT. Ein Fall von Ueberlegung beim Hund. *Arch. ges. psych.*, 6, 249, 1905.
2. CARR, H. Orientation in the White Rat. *Jour. Comp. Neur. & Psych.*, 18, 27, 1908.
3. COLE, L. W. Concerning the Intelligence of Raccoons. *Jour. Comp. Neur. & Psych.*, 17, 211, 1907.
4. COLE, L. W. Observations of the senses and instincts of the Raccoon. *Jour. Animal Behavior*, 2, 5, 299, 1912.
5. DAVIS, H. B. The Raccoon: A Study in Animal Intelligence. *Am. Jour. Psych.*, 18, 479, 1907.
6. FRANKEN, A. Instinkt und Intelligenz eines Hundes. *Jour. Animal Behavior*, 1, 6, 430, 1911.
7. GLASER, O. C. The formation of habits at high speed. *Jour. Comp. Neur.*, 20, 165, 1910.
8. HAGGERTY, M. E. Imitation in Monkeys. *Jour. Comp. Neur. & Psych.*, 19, 337, 1909.
9. HAMILTON, G. V. An Experimental Study of an Unusual Type of Reaction in a Dog. *Jour. Comp. Neur. & Psych.*, 17, 329, 1907.
10. HAMILTON, G. V. A Study of Trial and Error Reactions in Mammals. *Jour. Animal Behavior*, 33.
11. HOGE & STOCKING. Punishment and Reward as motives. *Jour. Animal Behavior*, 2, 1, 43, 1912.
12. HOLMES, S. J. The Evolution of Animal Intelligence.
13. HUNTER, W. S. The Delayed Reaction in Animals and Children. *Behavior Monographs*, Vol. 2, No. 1.
14. JOHNSON, H. M. Audition and Habit Formation in the Dog. *Behavior Monographs*, Vol. 2, No. 3.
15. MORGAN, C. LLOYD. Habit and Instinct. *Animal Behavior*.

16. SACKETT, L. W. A Study of the Learning Process in the Canada Porcupine. *Behavior Monographs*, Vol. 2, No. 2.
17. SHEPHERD, W. T. Imitation in Raccoons. *Am. Jour. Psych.*, 22, 583.
18. SMALL. Mental Processes of the Rat. *Am. Jour. Psych.*, 11, 112, 1900, & 12, 233, 1901.
19. THORNDIKE, E. L. Animal Intelligence. *Psych. Rev. Monogr. Suppl.*, Vol. 2, No. 4, 1898. *Psych. Rev.*, 6, 412, 1899.
20. WASHBURN, M. The Animal Mind.
21. WATSON, J. B. Animal Education.
22. WATSON, J. B. Imitation in Monkeys. *Psych. Bull.*, 5, 169, 1908.
23. YERKES, R. M. The Discrimination Method. *Jour. Animal Behavior*, 2, 2, 142, 1912.

THE LOCALIZATION OF SOUND IN THE WHITE RAT

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INTRODUCTION

The experiments presented in the following paper are intended as a preliminary study of the white rat's ability to localize sound. Meyer, Johnson, and Szymanski have also made preliminary studies, of less extent, however, upon other animals.

Meyer's¹ problem was to investigate (1) when and how localization appears in mammals and (2) the date of the appearance of the ability to localize correctly. As a result of his work he concludes that ability to localize depends upon: (1) mediate factors of vision, tactual sensations, habit and experience; (2) the immediate factor of hearing. Furthermore, he says true localization of the second type (hearing) is a function of binaural hearing, and mentions the factor of intensity. To test the above problems, he used humans and various species of animals: 47 human nurslings, 16 older children and 100 animals, 9 of which were less than a year old. With children he found that the difference between location of familiar and unfamiliar sounds seemed to be the essential factor. Six stages in the evolution of hearing were distinguishable in the human nurslings, comparable to the stages in the animals tested. The nurslings localized sounds as early as 7 weeks, although there was considerable variation. By the end of 6 months, however, practically all of them localized calls and noises. His work with animals falls into the following groups, a whistle furnishing the stimulus: (1) 2 dogs (5 days old) gave no reaction; (2) 1 Samali sheep (8 mo. old), 2 bears (6 mo.), attempted to localize sound but could not; (3) jaguar (5 mo.), elephant (5 mo.), leopard (13 mo.), panther-leopard, localized quickly and

¹ Meyer, Julius. Die Benutzung der Schalllokalisation zum Nachweis von Hördifferenzen; ihre Verwertung als Simulations-probe. *Monat. j. Ohrenhk.*, bd. 46, S. 1-15. 1912.

Weitere Beiträge zur Frage der Schalllokalisation. Untersuchungen an Säuglingen und Tieren. *Monat. j. Ohrenhk.*, bd. 46, S. 449-474. 1912.

accurately; (4) older animals, including lions, tigers, panthers, hyenas, bears, elephants, antelopes, zebras, sheep, angora goat, various species of apes, land and water turtles, and 2 serpents, all localized with varying degrees of accuracy. If the animal oriented to the sound, Meyer presumed that it was endeavoring to localize. Meyer has made a table cataloguing the reactions of all these animals. No very definite conclusions were gained because of the roughness of the experimentation.

Johnson² and Szymanski³ have each made a few tests on the localization of sound by dogs. (The latter author has worked with cats also.) Johnson found that his four dogs learned to go to the source of sound after from 105 to 165 trials. Szymanski's animals failed after from 21 to 30 (?) trials. (S. attributes the failure to the small size of the experiment box which measured 9m. by 2.7 m. More probable causes are the small number of trials given and the pernicious position habits that developed. Johnson's box was differently constructed. He does not give its dimensions in detail, but I judge it to have been 24 ft. by 12 ft. The variations in size in the two boxes are thus negligible.) In each experiment, the stimulus consisted of a sound (a buzzer with J. and a bell with S.) which could be given in either of two positions in front of and to either side of the subject. (4 m. away in S's work, about 10 ft. in J's study.) No attempt was made in either case to increase the number of positions in which the sound might appear; and in Johnson's work little or no attempt was made to determine the cues used in securing the positive results.

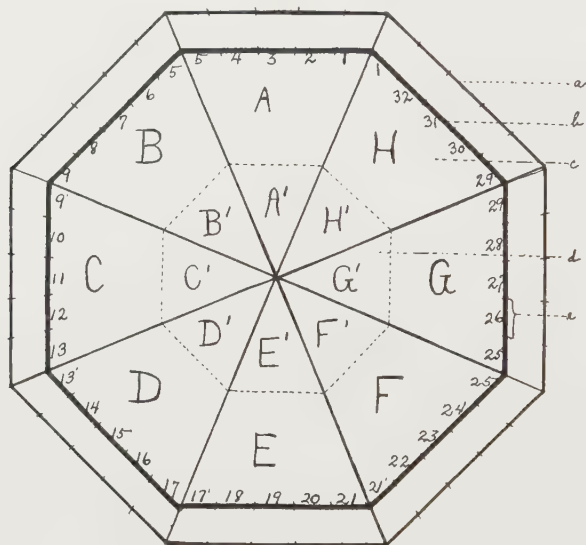
In the present paper, I have been concerned primarily with the following problems: (1) How accurately will white rats localize sounds? (2) To what extent does intensity (both absolute and relative) determine the accuracy of response? The results throw additional light upon several supplementary problems: sensitivity to tone and the nature of the learning process. The study was made at the University of Texas during the session of 1913-14, under the supervision of Prof. W. S. Hunter.

Notes on Animals Used. Seven rats in all were used during the experiment. Rats No. 4 and No. 6 (male) were obtained

² Johnson, H. M. Audition and Habit Formation in the Dog. *Behav. Mon.* vol. 2, No. 3, 1913. pp. 46-51.

³ Szymanski, J. S. Lernversuche bei Hunden und Katzen. *Pflüger's Archiv.*, bd. 152, 1913.

from a dealer, January, 1913. They were approximately 6 weeks old at the time. Rats No. 19, No. 21 (males) and No. 20, No. 22, No. 23, (females), reared in this laboratory, were about 2 months old at the time the experiment was begun upon them (October, 1913.) No. 19 was dropped after the first preliminary trials upon methods of learning, because the method in which it had been trained was discontinued. The older rats were more deliberate in their movements than the younger.



F₁ q. I.

FIGURE 1. Ground plan of apparatus. a, the stimulus board; b, the main apparatus box; c, outer triangle; d, inner triangle; e, section (approximately 2 ins. wide).

APPARATUS AND GENERAL METHOD

A. *Apparatus. Apparatus Box*—The apparatus in the present study consisted of an eight-sided box surrounded by a stimulus board. (See Figs. I & II.) All was made of light wood. The floor of the box was divided into isosceles triangles, lettered A, B, C, etc., in order to facilitate the noting of the positions of the rat. The sides of the box were divided into 32 sections all of which were

approximately 2 inches wide with the exception of the corner ones which were from 3 to 4 inches wide. The stimulus board, 2-1/2 inches away from the main box, was fastened with wooden pegs to the table. This was done to prevent, as far as possible, the vibrations from passing through the wood between the point of sounding the stimulus and the point where the rat was standing. An opaque screen containing peep holes was erected about the apparatus in order to conceal the experi-

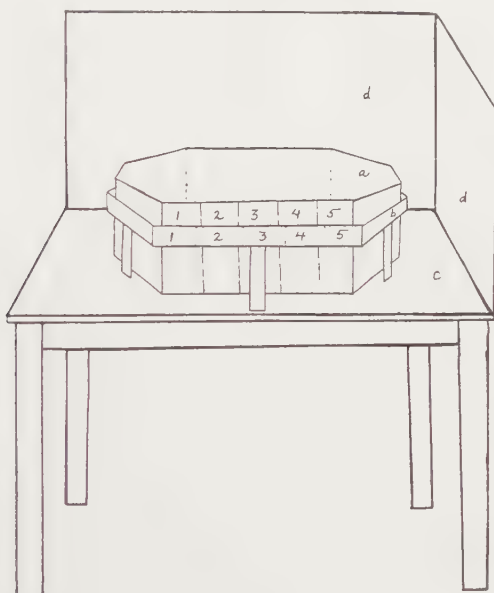


Fig. II

FIGURE 2. Entire apparatus in perspective. a, main apparatus box; b, the stimulus board; c, the table; d, two sides of the screen behind which the experimenter stood.

menter from the view of the rats. Measurements of the apparatus are as follows:

Minimal width of box.....	22 in.
Length of sides.....	9-9 1/2 in.
Height of sides (inner).....	7 7/8 in.
Distance of stimulus board from box....	2 1/2 in.

Length of sides of stimulus board.....10 1/2-11 1/2 in.
Width of stimulus board.....3 in.
Height of stimulus board from table.....3 1/4 in.

The box had inevitable defects. (1) The fact that no release box was used allowed the rat to wander at will, getting the stimulus from different angles and positions. No constant standard head position could be gotten. (2) The reflection of the sound probably differed as the rat was nearer to the center or to the side of the box. Finally, (3) the sound might be diffused along the boards and thus prevent very accurate localization. However, in spite of these defects, the localizations were quickly and comparatively accurately made.

Various methods suggest themselves by which a relatively better control of the position of the rat with respect to the point of origin of the sound could be obtained. This of course is one important feature necessary for a comparison of animal experimentations with the human work in the localization of sound so far accomplished. Perhaps Pawlaw's salivary method would offer the best solution of the difficulty in tests with such animals as are suited to the method. The animal's head here could be fixed in a stationary position during the test. Presumably, after the association of a definite localization of the sound stimulus with food had been set up, the animal could be tested for the accuracy of change of localization in the different planes. This accuracy would be measured in respect to the quantity and quality of the flow. Monaural hearing should be tested here also.

Stimuli—The standard instrument for giving the stimulus (a tapping upon the stimulus board) was a medium weight chisel, the tapping of which had a predominant pitch between 256 d. v. and 512 d. v. This was determined by the use of Helmholtz resonators. Other stimulus sounds were made by: (1) tapping upon the stimulus board with the rubber of a lead pencil; (2) sounding a 256 d. v. tuning fork outside the screen; (3) giving the interrupted tone, 256 d. v., on an organ pipe; (4) hissing through the teeth; and (5) tapping with a lead pencil rubber upon the resonator box of a 256 d. v. fork. In giving this last stimulus, the resonator box was held in the hand outside the screen, and was tapped on the upper surface 1/4 of the

distance from the opened to the closed end or half way between the open end and the fork. The intensity of the resulting sound was approximately the same as that made by the pencil (6 1/2 gr. weight) when dropped from the height of three inches upon the resonator at the same point used in the tapping. Here, as in the giving of the stimulus, the resonator was held in the hand. The intensity of the sound of the chisel was roughly the same, while the intensity of the tapping on the stimulus board with the lead pencil rubber was approximately equal to that caused by dropping the pencil above used on the resonator box from a height of one inch only.

The interrupted tone on the organ pipe was given for comparison with the interrupted noise produced by tapping. The stimulus from the fork and the hissing were comparable in that both were continuous in character. To the experimenter, the sound of the 256 d. v. fork seemed lower (undoubtedly due to the absence of overtones) than the tapping upon the 256 d. v. resonator box although both resounded to the Ut 3 Helmholtz resonator. The former was also decidedly more characterless.

B. *Description of Method*—The problem which the present experiment set the rat was the establishment of an association between the location of a sound (normally the tapping upon the stimulus board) and food. The experiment fell into three periods, which may be characterized as follows: (1) a period in which the rat was fed inside the box in order to accustom him to the apparatus and the experimenter; (2) a period of learning the association between tapping and getting food at the point of tapping; and (3) a control period in which the determining cues for the behavior were sought.

The procedure of each trial of the regular tests was as follows: (1) The position of the rat was noted at the moment of tapping. This included the direction of his head in respect to the section tapped as well as the absolute position of his body in the box. (2) The tapping signal was given on the stimulus board at the middle of a certain section. This tapping was *continued until the rat stood up at some section on the side of the box*. (3) The path of the rat from his starting point to the standing up point was noted. (4) Finally, the rat was *fed at the section tapped* to which he had to come if he had incorrectly localized elsewhere. No punishment was given if the rat did not react

correctly, with the possible exception of the fact that he was consequently delayed a moment or two in being fed. As the rat was allowed only a nibble of the bread held over the side of the box, his zest for the work was not impaired during the 8 trials given per day. The records were noted in symbols, e. g. \leftarrow A' tq B' C D 16-14. Interpreted, this means that the rat was standing in the inner triangle, A' (see fig. 1), headed away from the experimenter (\leftarrow) when the signal was given, turned quickly (tq), went through triangles B', C, D, standing up finally at section 16 in D, while the experimenter was at section 14.

The accuracy of localization is therefore .2. A regular series of presentations was used, in which each of the 32 sections of the box (see fig. 1) was given once every four days while each side of the box was given once every day. The order was as follows:

1st day	A	D	B	F	C	H	E	G
	1	16	8	21	10	30	19	27
2nd day	B	F	D	H	E	G	C	A
	6	23	15	32	17	26	9	4
3rd day	C	H	F	A	D	E	G	B
	12	29	22	2	13	18	28	7
4th day	D	A	C	H	F	B	G	E
	14	3	11	31	24	5	25	20

The capitals stand for the different sides of the box; and the numbers for the sections. Daily records were tabulated from the reactions of each rat by averaging the eight trials. The results are in terms of error, i. e., of accuracy of localization, denoting how many sections the rat missed the point of tapping. The reaction of the rat was considered completed when he stood up, and no further record was made for that test, regardless of subsequent behavior.

After the rat had been trained to a degree of accuracy which was reasonably constant from day to day, whereby the fact was established that the animal was localizing something, the next phase of the problem was considered, viz., was the reaction an auditory one. To establish this point controls were put in

which eliminated kinaesthetic, olfactory and visual cues. Then, since the association still persisted, an effort was made to discover the auditory factors determining the accuracy of localization.

Several difficulties arise under the present plan of experimentation: (1) the rat, although alert and eager to respond, has to inhibit its own movements; (2) the tendency is to go in the direction headed (see fig. 3, below p. 307); (3) a reflex recoil is manifest at unwonted, unexpected noises; (4) flightiness or unstable attention is present; and (5) no punishment was given for incorrect responses, a condition which probably lessened accuracy and quickness of learning. These factors are all of importance in differentiating animal work from that done on humans. In addition one should note the difference in recording judgments in rats and humans, for the latter have only to indicate the point localized or to respond according to a familiarized chart, while the former have actually to go to the correct section.

EXPERIMENTAL SECTION

A. *The learning of the association*—The first question, i. e., whether the rat could localize the noise, was quickly answered, for an accuracy which was not improved in degree throughout the later part of the experiment was obtained within from 40 to 136 trials, i. e., in from 5 to 17 days. Table 1 shows the number of trials necessary for each rat to reach the standard reaction, which was considered achieved when the rat did not vary markedly in response for several days.

TABLE 1

Rat	6	20	4	21	22	23
No. trials on learning	136	40	136	64	48	48

An interesting observation in connection with this table is that rats 6, 4 and 21 were males, while rats 20, 22 and 23 were females. This difference in trials on learning may be due to chance, or to the fact that rats No. 6 and No. 4 were older than the others.

Records of the average daily error for rats No. 21, No. 22, and No. 23, for the first 15 days are in Table II.

TABLE II.

Rats	No. 21	No. 22	No. 23
1st day	3 2/7	6 6/8	6 4/8
2nd day	3 2/8	5	6 4/8
3rd day	3 2/8	4 3/8	4 5/8
4th day	4	4 5/8	4 5/8
5th day	1 4/8	1 5/8	6/8
6th day	1 5/8	3 6/8	5 3/8
7th day	2 5/8	1	1 2/8
8th day	3	7/8	1 7/8
9th day	1 4/8	2 2/8	1 2/8
10th day	2 7/8	1 6/8	4 6/8
11th day	1 (I)*	1 1/8 (I)*	2 2/8 (I)*
12th day	3 1/8 (II)*	2 3/8 (II)*	1 4/8 (II)*
13th day	1 5/8 ("*)*	3 1/8 (II)*	1 4/8 (II)*
14th day	2 4/8	6/8	1 5/8
15th day	6/8	1 5/8	1

* On these days controls were put in, but as they did not affect the rats' reactions the trials were considered standard.

The high average of No. 23 on the 10th day was doubtlessly caused by the noise in the laboratory resulting from an electric storm. One bad reaction of No. 22 on the 13th day, accounts for the high average, for the other reactions were up to standard. The average for No. 21 on the 12th day can be accounted for in a similar manner.

Throughout the tests the responses of the rats never became automatic. If a curve were plotted of these normal responses, it would show marked irregularities throughout its course. This contrasts with the regularity of the ordinary maze co-ordination in rodents—a motor or kinaesthetic habit.⁴ Other investigators working with other problems have noted a similar irregularity in certain sensory habits. For example Vincent⁵ in studying the ability of the white rat to learn the maze problem when olfactory and visual stimuli had been added and utilized secured results of this type. Watson⁶ and Hunter⁷ point out a similar lack of automaticity in the maze habits of birds. A

⁴ Watson, J. B. Kinaesthetic and Organic Sensations. *Psych. Rev. Mon.*, vol. 7, No. 2, 1907.

⁵ Vincent, S. B. Some Sensory Factors in the Maze. *Psych. Bull.*, vol. 10, p. 67, 1913.

⁶ Watson, J. B. The Behavior of Noddy and Sooty Terns. *Carneg. Inst. Publ.*, No. 103, 1909.

⁷ Hunter, W. S. Some Labyrinth Habits of the Domestic Pigeon. *Jour. Animal Behav.*, vol. 1, 1911.

thorough study of the factors governing these curve differences has not been made at the present time.

The length of the periods of learning the auditory localization in our problem are interesting when compared with an experiment on the effect of using food as the stimulus object performed by Mr. A. C. Scott in this laboratory. He had two problems for comparison. In one the rats set up an association between the appearance of a light in one of two boxes and being fed at a point immediately over the light, i. e., a problem in which the animal learned to eat the light stimulus, we might say. This is comparable in every way with our problem in which the rats "ate the auditory stimulus" in so far as they understood the problem. The association in Mr. Scott's experiment was learned in 30 trials, the best of our rats learned in from 40 to 64 trials. In Mr. Scott's second problem, the rats were trained in the same Yerkes discrimination box to respond to the presence or absence of light by running in the proper direction through the box. The food was placed in the rear of the home box from which they started. This association was learned in not less than 120 trials. It seems reasonable to conclude, therefore, that one large factor making for rapid learning in our tests was the use of the food object for the stimulus. There are two other possibilities which would need to be seriously considered in an exhaustive study of this matter. The localization of sound may be largely an instinctive capacity; or it may be a capacity which was considerably developed in the ordinary life of the animal before the present tests were begun.

The learning of the association between source of sound and getting food fell into four main stages. In the first few trials, the rats apparently disregarded the auditory stimulus while seeking for some other cue as a guide. Visual (?) cues were used predominately, i. e., the appearing of the hand over the side of the box with food (this occurred only after the rat had made the reaction of standing up at some point), and movements of the screen. Olfactory cues seemed to be sought, for the rat frequently sniffed in all directions before responding. In the second stage, an awareness of the tapping was evidenced. This was indicated by a quick onward start when the stimulus was given. However, the animal did not seem to realize that this was a cue to the correct direction of the food, merely that it

was a signal for response. The third stage of the learning was one in which hesitancy was manifested when the stimulus came. The rat would turn his head in all directions before deciding in which direction to go. During the rest of the reactions (embracing the fourth division of the learning of the association) the attention was placed predominately upon the proper stimulus. The progress during this stage was an increase in accuracy.

B. *Control period*—Now that the first question of the problem has been answered, i. e., can the white rat localize noise, the other two questions arise: (1) Is this an auditory reaction? (2) What factors determine accuracy of response? Twelve different control tests were put in to investigate these points.

a. *Visual controls*—To eliminate visual cues which might have been gotten from the operator, a screen of black cloth was fastened around the table, as has been indicated. Furthermore, the operator constantly stood so that the angle from the section tapped varied from trial to trial. A conclusive proof that the rat was not using the operator as a guide occurred elsewhere, e. g., in control III. when the sound of a vibrating tuning fork was used as a stimulus. Here the rat broke down entirely. If the rat had been reacting to a visual cue or even to any type of cue from the experimenter, the response would have been as accurate as before.

b. *Olfactory control (I)*—As the rats frequently stood up and sniffed in all directions before responding, odor was considered a possible cue in that food was always held in the experimenter's hand. Accordingly, small pieces of bread soaked with milk (the food used as the reward) were laid along the edges of the box in order to distribute the odor uniformly. The reaction remained normal. The odor appeared possibly to stimulate the rats in quickness of response, but no confusion arose. To serve as a further check, throughout the experiment the food was held at different angles to the point of stimulation. Final proofs were: (1) that the rat would respond accurately when the experimenter had no food in his hand; and (2) that the reaction broke down when the auditory stimulus suffered certain changes as recorded below.

c. *Kinaesthetic-tactual control (II)*—Another possible guiding cue was the kinaesthetic-tactual sensation gotten from the vibrations in the floor of the apparatus box when the stimulus

was given. This had been eliminated as far as possible by fastening the stimulus board to the table and not to the main apparatus box. In control II, a layer of cotton batting 1 in. thick was placed under the apparatus box in order further to eliminate vibrations. The resulting responses were at normal accuracy. A final argument to prove conclusively the non-essential character of the vibratory cue was found in control III where the substitute stimulus, a resonator box, was held in the hand outside the screen. Extraneous vibrations were here eliminated, yet the reactions were made at a normal accuracy.

The elimination of olfactory, kinaesthetic-tactual and visual cues indicated that the response of the rat was determined by auditory factors. The problem now concerned the auditory factors determining the accuracy of localization. Other auditory timbers and pitches, the interrupted character of the stimulus and intensity were investigated.

d. *Auditory controls*—For use in later comparison, a preliminary control (III) was put in. A stimulus noise was found which was of a predominant pitch 256 d. v., and of an interrupted character. This was the tapping upon a resonator box with the pencil rubber as described above in the section on apparatus. The pitch was determined by Helmholtz resonators. The intensity has also been described previously, and was approximately equal to that of the chisel which gave the normal stimulus. Thus in this control, we have a predominant pitch 256 d. v., the interrupted character of the sound and the standard intensity. The reactions, which showed no break from the normal accuracy, were as follows:

TABLE III

Rat	6	20	4	21	22	23
Normal	6/8	2 1/8	1 1/2	1 5/8	3 3/8	1 2/8
Con. III	3	1 5/8	2 1/4	1 1/8	2 1/8	1 3/8
Con. III	1 7/8	1 3/8	2 1/8	1 1/4	2 1/2	

The three series of averages shown, were secured on three successive days.

Whether or not the pitch element *per se* of the standard stimulus was the fundamental factor in determining the locali-

zation was the next problem (control IV.) The stimulus was given by striking a tuning fork of 256 d. v., attached to its resonance box. The open end of the resonator was held at the given section of the apparatus box. Accuracy averages for this stimulus are given in table IV. The negative results indicate

TABLE IV.

Rat	6	20	4	21	22	23
Normal	6/8	1 5/8	1 6/8	6/8	1 5/8	1
Con. IV	4 5/8	5 3/8	8 3/8	4 1/2	6 3/8	11 1/2
Con. IV	.8 5/8	7 3/7	7 6/7	8 1/4	8 1/8	6 1/8

that the mere presence of a given pitch was not guiding the reactions. But more than this, it would seem either that the animals are unable to localize pure tone or that they are deaf (absolutely or relatively) to the one here employed under the present experimental conditions. In the light of Prof. Hunter's tests, the latter alternative is undoubtedly the correct one.⁸ It is important to note here that a response of some accuracy, i. e., standing up at some point along the side of the box, was made by the rats throughout the experimentation regardless of the nature of the stimulus. Thus our method is not crucial on cases of mere sensitivity because results are stated solely in terms of accuracy. Inasmuch as the rats had been taught that food was over the side of the box, they could not be expected to remain inactive for any considerable interval of time; and, in fact, they went from one section of the box to another, standing up each time. A trial was not considered complete until the rat had stood up in such a manner.

The most significant data are derived from an observation of the animals' general behavior during the stimulation. Quickness of response, alertness, head-turnings for localization are all present when the standard stimulus are given. No attention was paid to the stimulus in control IV. The animals wandered indifferently about the box exactly as they always did between the regular tests. Several times the animals jumped when the fork was struck; however, there were no indications of an effort

⁸ Hunter, Walter S. The Auditory Sensitivity of the White Rat. *Jour. Animal Behav.*, vol. 4, No. 3, 1914.

to localize during the continuance of the remainder of the stimulus. The same response was made when the fork was dampened and the thud of striking only was given.

It is worth while noting that the pitch in control IV was the same as the predominant pitch in control III. The intensities also were as close to equality as possible. Results⁹ secured on the rat's ability to discriminate intensities of tone would suggest a very poor sensitivity to intensity differences. As a result of these relations, a further question arises in regard to the physiological basis for the perception of noise and the perception of tone.¹⁰ The fact that a tone 256 d. v. is ignored while a noise 256 d. v. is reacted to accurately may indicate a separate basis for the two perceptions (or, as stated above, in the light of other work it may be due to deafness to tones of a certain pitch). The problem must be carried much further, of course, before definite conclusions can be drawn.

(Con. V) In order to test the interrupted character of the stimulus as a predominant factor in governing accuracy of response, 256 d. v., on an organ pipe was tooted. Although this too was of the same pitch as the tapping stimulus in control III and was a klang and not a simple tone, the accuracy of response was just as disturbed as with control IV. The responses seem to have been made by chance, for there was much aimless wandering and apparently no attention was paid to the sound in the great majority of cases. The reasons for the breakdown of the reactions may be either (1) inability to hear the tone 256 d. v. no matter whether simple or complex or (2) the fact that the stimulus was too different from the standard stimulus to be recognized. It must be noted, however, that the interrupted character of this stimulus elicited no better response than the continuous tone of the tuning fork while the tapping on the resonator box gave normal results. This is again in strict harmony with the results obtained by Dr. Hunter in his work (p. 221) on the auditory sensitivity of the white rat above referred to.

(Con. VI) This control, further questioned the interrupted character of the stimulus as the primary factor. The stimulus used was hissing through the teeth, a continuous sound. The

⁹ Hunter, the last article cited, pp. 219-20.

¹⁰ Nagel's *Handbuch der Physiol. der Menschen*, Bd. 3, S. 585, 1905.

matter was not investigated with sufficient thoroughness to obtain conclusive results because of lack of time. Four rats evidently heard the sound and endeavored to locate it, although their attempts were attended with very poor accuracy. The sound apparently had no meaning for the other two animals. The reactions of the first four, fall, in accuracy, between those of control III and those of control V. It seems evident that the quality of the stimulus aids in the present localizing response. Whether the rats can actually localize an interrupted sound more accurately than a continuous one, I am not prepared to say. The issue in the present case may have been one of familiarity vs. unfamiliarity.

Our attention was next directed to the place of intensity among the essential factors, determining the standard accuracy of response.

Very loud tapping with the chisel was used to test the effect of strong absolute intensity (con. VII.) The animals were startled and nervous, but their reactions were up to the normal accuracy. A light tapping (con. VIII), was next tried of an intensity not much more than just perceptible to the experimenter. Here the rats moved more slowly than usual, but maintained an attitude of alert attention. They seemed confused and in doubt, though ready to respond. The stimulus may have been below the threshold in some cases with each rat, if the matter is to be judged by aimless wandering during the giving of the stimulus. The accuracy of response was slightly decreased.

As absolute intensity, within the range used was not the essential factor, relative intensity was tested. What we were striving towards was data which would indicate that the rat's responses were governed by the relative intensity of the sound to its two ears. In the first control (IX) a double stimulus was used, necessitating two operators (Hunter and Barber). Hunter tapped heavily at the allotted section while Barber tapped lightly directly opposite. The tapping was always begun when the rat was half way between Hunter and Barber. The stimuli were given as nearly at the same moment as possible, but the louder one was always slightly earlier in that it was used for a signal for Barber to begin the lighter tapping. Thus, the difference was measured by the length of Barber's reaction

time. Results, reckoned in accuracy in respect to the sections tapped by Hunter, are as follows:

TABLE V.

Rats	20	21	22	23
Normal	2 3/8	2	2 7/8	1 1/2
Con. IX	2 7/10	3	2 11/12	2 9/11
Con. IX	7/8	2 10/11	6/8	2 6/8
Con. IX	1 1/2	3 6/8	3 1/2	

As a rule the rat went to the heavier tapping, as may be seen from the results.

The question at once arose whether the first tap did not direct the rat's localization. Accordingly, a similar control was installed (X) in which the lighter tapping was begun first, acting as a guiding signal to Hunter. The control was not entirely comparable to control IX, however, for in order to insure the fact that the lesser intensity was perceived, the rat was always allowed to make a decided start towards the lighter tapping before the heavier was begun. In spite of this decided advantage for the lesser intensity, the reaction broke down in accuracy, i. e., they failed to choose the lesser intensity. This shows that the mere giving of the sound first by Hunter in control IX did not determine the response to the heavier tapping. Results reckoned in accuracy in respect to the sections tapped by Barber, are given in Table VI.

TABLE VI.

Rats	20	21	22	23
Normal	2 5/8	1 3/8	1	7/8
Con. X	8 1/8	7	8 7/8	10 7/8
Con. X	11 2/8	10	10 1/8	8 5/8

The following reaction is typical of the responses made:

→ hh t
 B' on A' A 4 B C D 13 (H 29.) Interpreted, this means that the rat was in triangle B' (see fig. 1) headed towards the lesser intensity when the tapping was begun (B'), went on to

A and then hesitated when the heavier tapping was begun
hh

(A), stood up at point of hesitation (4), turned towards the heavier intensity, and responded accurately to this (D13). Barber was at H29. The error, which was noted in respect to the first standing up and not in terms of the final decision was 7. From these results it is apparent that the first taps do not determine essentially the final reaction. The table further makes it clear that the rats went to the loud sound although headed toward the faint one. This is important when viewed in the light of the curve in fig. 3 which shows that the rats tended to go in the direction they were pointing.

A test further questioning the effect of the first few taps was given in control XI in which alternate tapping was made the stimulus. Hunter tapped once heavily, and then Barber tapped once less heavily, etc. The results show that as a whole the rats chose the stimuli indifferently. However, in two cases (No. 20 and No. 23) reactions to the heavier tapping predominated. No evidence was obtained that the first tap determined the point finally localized. A conclusive test of the influence of the first taps was given by control XII. In this the operator tapped only three times and then stopped, not continuing until the rat stood up as in the standard tests. Little of interest is shown in the results as tabled; however, the experiment was of importance for the observations made of the rats' reactions. The rats started as usual for the right point, but then showed great hesitancy and confusion when the stimulus stopped. Usually, however, the impetus gotten at first was great enough to secure a fair accuracy of response. The indications plainly were that the determination of the general direction of the stimulus was a matter of the first taps, while the accuracy of response was dependent upon the continued tapping. Evidently the rat utilized the whole stimulus in making his normal reaction.

Involved necessarily in this question of relative intensity is the problem of the binaural ratio. In control IX, double stimulus of two intensities, the rat was sideways to each of the operators at the beginning of the stimulus, but after the first movement, conditions were changed. Thus, no definite statement can be made in respect to the binaural factor as a cue throughout the control. A very careful effort was made to

determine the relative accuracy of the rat during the standard reactions in regard to the three bodily positions, namely, when headed towards the operator, when headed away and when sideways. Many tables and curves were constructed, but no conclusions bearing upon the ratio in question were reached. (It

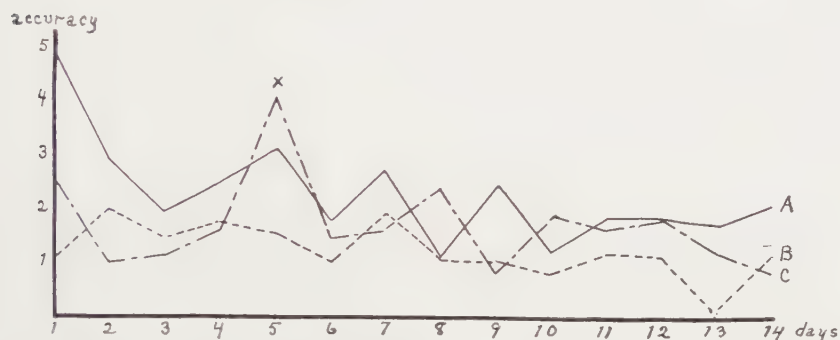


FIGURE 3. Average accuracies per day of rats 21, 22 and 23 showing, a, accuracy with head pointed away from section tapped, b, accuracy with head pointed toward section tapped, and, c, accuracy when rat was sideways to the point of stimulation. A storm occurred at x.

is well in this connection to bear in mind the writer's comments upon general method made above, pp. 299.) Figure 3 brings out the not unexpected fact that the rat's greatest accuracy came when it was oriented toward the source of stimulation. When the animal was oriented sideways to the stimulus, it reacted with the next degree of perfection. The least accurate responses occurred when the animal was headed away from the stimulus.

C. *Tests on Retention*—In order to discover the degree of permanency in the localization-association, memory tests were made upon the six rats after various intervals in which there was no training. Rats No. 4 and 6 were tested first after an interval of 40 days and then after an interval of 38 days. In each case there was essentially perfect retention. (See table VII.)

TABLE VII.

Rats	4	6
Dec. 18	2 1/2	1 1/2
Jan. 29	4 4/8	1 1/8
Jan. 30	3 6/8	3/8
Mar. 8	2 1/2	2

Rat No. 4 raised his averages, January 29 and 30, by making three bad reactions each day. The other trials however, were of normal accuracy. Rats No. 20, 21, 22, 23, were tested after a rest period of nearly a month (Feb. 11-Mar. 8) Table VIII.

TABLE VIII.

Rats	20	21	22	23
Feb. 8	3 5/8	1 3/4	1	1
Mar. 8	2 1/4	3 7/8	3 1/8	1 1/2

The younger rats, No. 20, 21, 22, 23, seemed less certain of the correct response than did the older rats, particularly No. 6, but retention was evidently present. No. 22 broke down on the first two trials given, making an average of only 5-6 on the last six. No. 21 seemed indifferent to the stimulus as a rule, although he made several perfect reactions. The small number of rats used however will not permit correlation between age and accuracy of memory. It must be remembered that although the rats were not tested during the period of rest, they still had some practice in that they would run to the sides of the cage when anyone entered the room. This however will not account for the accuracy manifested in the memory test.

SUMMARY AND CONCLUSIONS

1. The white rat is able to localize a noise with an average accuracy of from 2 to 4 inches under the conditions of the present experiment. This means, of course, 2-4 inches on either side of the point of stimulation, so that while in a single trial the accuracy is as just stated, and, let us say, to the right of the source, the next time it may be an equal distance to the left. The total space covered is, therefore, from 4 to 8 inches.

2. The association between such an accuracy of localization and food is established in from 40 to 136 trials.

3. The response is to an auditory cue, for those from vision, odor and kinaesthetic-tactual sources were eliminated from the experiment without change in the accuracy of response.

4. The auditory factor which in general determines the accuracy of localization is probably the relative intensity of the

sound to the two ears. Further tests must be made before this is established beyond question.

5. In control tests, the rats were not only unable to localize pure tones from tuning forks, but they absolutely ignored them. The same behavior was manifested toward klangs as sounded on an organ pipe.

6. A noise of 256 d. v. predominant pitch was localized while a tone of the same pitch was ignored. This has a bearing upon the problem of sensitivity to noise with insensitivity to tone, and with Prof. Hunter's work, it may point to separate bases for the perception of noise and tone.

7. There is evidence to show that if a rat is trained on an interrupted noise, it is disturbed in its accuracy of response by the substitution of a continuous noise. It is impossible to say at present whether the difference is intrinsic or not.

8. The present localizing-association was retained practically unimpaired for 40 days during which there was no training.

THE AUDITORY SENSITIVITY OF THE WHITE RAT

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INTRODUCTION

The present paper is a continuation of the research upon the auditory sensitivity of the white rat reported in volume 4 of this Journal¹. That paper and the present one should be read in conjunction with an article on the localization of sound in the rat by Miss Barber². The three together present a large array of data upon the sensitivity of the white rat to tones in

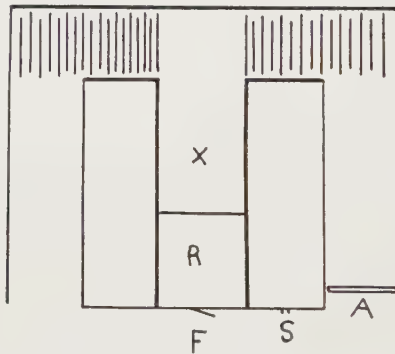


FIGURE 1. (Reprinted from volume 4, page 215, of this Journal.) T shaped discrimination box. F, food; R, release box; X, tuning fork was held above this point; A, alley stop, can be placed in either alley; S, switches.

the lower part of the pitch scale. The results have been accumulating since January, 1913, and so far as I can detect are all consistently opposed to the conclusion that the rats are sensitive to tones of the pitch used. Perhaps I should add "under the present experimental conditions," but I can see no reason for doubting that the method employed offered a perfectly fair test of the rat's ability.

The same apparatus and method were used in the present

¹ Hunter, Walter S. 'The Auditory Sensitivity of the White Rat. *Journal Animal Behavior*, vol. 5, no. 4, 1915.

² Barber, Alda Grace. Localization of Sound in the White Rat. *Journal Animal Behavior*, vol. 5, no. 4, 1915.

tests that are described in the earlier account. For the sake of clearness, it may be well to describe these again. Figure 1 is the T shaped discrimination box. The rat was expected to associate a turning to the left in order to secure food placed at F with one stimulus, and the opposite turning with another stimulus. The forks and whistles of the present tests were mounted above x. Other stimuli were given just back of the discrimination box where the experimenter stood. In the present work, the release box was not used. The animal was placed in the door at F after the stimulus had been started. Punishment and reward were used with all the rats. Unless otherwise stated in this paper, the following series of presentations (10 trials daily) were used:

lrlrrrrlr The present tests were carried out during the quietest
 rlllrrlrl part of the day under practically ideal conditions so
 llrrllrrl far as extraneous noises were concerned.
 rllrrlllr

EXPERIMENTAL RESULTS

I

Four young untrained rats were tested with the tuning fork 896 d.v. In order to respond correctly in the present test, the rat should turn through the right pathway when the fork was sounded and through the left pathway when the fork was not sounded. 700 trials (70 days) were given; but the rats not only failed to learn the association, they never improved essentially during the tests. Table 1 gives the number of correct reactions out of each succeeding fifty of the 700 trials.

TABLE 1

Trials	Rats			
	29	30	31	32
50.....	16	25	23	27
100.....	22	26	27	20
150.....	24	23	24	25
200.....	22	22	17	26
250.....	27	22	21	23
300.....	24	22	20	23
350.....	29	25	27	18
400.....	26	27	28	24
450.....	26	30	27	27
500.....	21	28	18	25
550.....	28	25	30	31
600.....	25	27	28	26
650.....	23	24	27	28
700.....	28	27	22	27

II

Learning Tuning Fork Chord—Tests were made upon 4 rats in an attempt to set up an association between turning to the right and a chord composed of the tones 512 d.v. and 640 d.v. (both sounded on tuning forks) and between turning to the left and the absence of the chord. Two of the rats (Nos. 37 and 38) were untrained. The other two (Nos. 31 and 32) had gone through the tests with the fork 896 d.v. cited above. Table 2 summarizes the results. It will be seen from that that none

TABLE 2

Trials	Rats			
	31	32	37	38
50.....	27	30	22	21
100.....	27	29	26	26
150.....	26	26	25	23
200.....	26	26	23	29
250.....	23	26	23	22
300.....	22	25	29	25
350.....	33	31	26	24
400.....	28	30	21	26
450.....	35	23	16	19
500.....	38	31	26	26
550.....	33	24	24	32
600.....	31	24	26	27
650.....	31	31	24	33

of the rats learned the discrimination within the 650 trials given. During this time there was a slight improvement in the reactions of numbers 31 and 38; but not in the case of the other rats. No. 31 ran as high as 76% and No. 38 as high as 66% during a period of 50 trials. Although these rats had begun the tests with an accuracy of 54% and 60% respectively, it was deemed advisable to put in controls and attempt to determine the factors guiding the responses.

Controls—The following controls were used: 1, chord *not* sounded. Other conditions as usual. Reaction counted wrong if it did not fit the series of presentations. 2, end-stops were placed in each alley as opposed to one alley. The chord was not sounded. Other conditions as in control 1. Using end-stops in each alley served to equalize atmospheric conditions in the two pathways. It appeared to the writer within the realm of possibility that the rats might be able to detect a freshness of the air through the open pathway which would not be present in the closed one. Their behavior was hesitant and

harmonized a priori with such an hypothesis. As soon as a rat had chosen the proper pathway, the end-stop on that side was quickly and noiselessly removed so that by the time the rat reached the alley on the side of the box a free exit was offered him. 3, no end-stops; no punishment; no chord sounded. Reactions right when they fit the series of presentations. If the rat chose wrongly, he was confronted by an open pathway to the food. In this control, even the punishment due to a blocked pathway was removed. This and the following control were used to test the rôle of kinaesthetic factors or position habits. Control 3 sought the character of these habits when uninfluenced by punishment. 4, conditions the same as in control 3, save that the electric shock was used when errors occurred. A quick interposition of the end-stop prevented the animal from reaching food when it chose the wrong alley. It was thought that the introduction of such punishments might lead to changes in the position habit as revealed in control 3. 5, no end-stops; everything else normal (as in standard learning series.)

The results attending the introduction of the controls are

TABLE 3

Nature of test	Number of trials	Rats		
		31	32	38
Con. 1.....	20	65%	65%	65%
Normal.....	20	70%	65%	60%
Con. 1.....	20	75%	65%	65%
Con. 2.....	20	50%	60%	...
Con. 3.....	30	...	...	53%
Normal.....	20	70%	60%	...
Con. 1.....	20	...	...	60%
Con. 2.....	20	45%	...	...
Con. 2.....	30	...	...	46%
Con. 3.....	20	...	65%	...
Normal.....	40	72%	...	...
Con. 1.....	10	...	...	40%
Con. 4.....	20	...	40%	...
Con. 1.....	20	...	60%	...
Con. 2.....	40	52%	...	...
Normal.....	50	68%	...	...
Con. 1.....	30	63%	...	...
Normal.....	50	74%	...	...
Con. 5.....	10	80%	...	...
Con. 3.....	20	65%	...	...
Con. 1.....	30	66%	...	...
Normal.....	60	70%	...	...
Con. 2.....	20	60%	...	...

Records are given in their chronological order. Correct responses are given in per cents. Rat 37 was not tested.

given in table 3. The significant fact from the standpoint of tone sensitivity is that the animals maintained their relatively high percentage (60% to 75%) of correct reactions *when the chord was not sounded*. This is conclusive proof that the slight improvement in accuracy found in the learning records in no way depended upon tone sensitivity. In other words the rats showed themselves as unable to respond to a fairly complex klang as to a simple tone.

The remaining controls were not worked out in detail with rats 32 and 38. The diary records indicate clearly that the responses were governed by position habits. Rat 31 was tested more fully. There are two chief points of interest in the data secured through these controls, (1) a high percentage of correct responses can be made on the basis of position (kinaesthetic) habits even though the series of presentations is very complex and cannot be said to be learned; and, (2) simple alternation seems to be the fundamental position habit. Although data with control 4 are lamentably lacking, it seems probable, from reasons given below, that the position habits were affected by punishment.

Control 2 did not disturb the reactions of rat 32, but did slightly those of rat 38. Rat 31 was undoubtedly affected by closing up both alleys. This was not a disturbance due to a changed visual (brightness) condition in the alleys, because the relation of the apparatus to the source of light precluded this. It would seem that normally rat 31, and probably rat 38, was greatly dependent upon the atmospheric conditions (freshness and better air circulation) of the two alleys. This is only advanced as a probability. Tests made directly upon the rat's ability to discriminate such stimuli offer the only definite approach to a solution of the question.

Controls 4 and 5 had no effect upon the animals tested. The poor percentage made by rat 32 with control 4 is to be accounted for entirely in terms of peculiar position habits. Part of the time a simple alternation was present; part of the time there was alternation after a success only. Control 3, by leaving both alleys of the apparatus open, permitted the rats' position habits (or kinaesthetic controls) to assert themselves in an unmodified way. In every case where this control was used, the rats tended to fall back immediately upon the method of simple

alternation between the two alleys. For example the series llrrllrrlr is given and the animal chooses as follows lrlrlrrlr. The reaction is 70% correct and yet there is only one reversal (underscored) of the series of alternations. Again the series rllrrlllr is given and the rat alternates with no reversal making 60% correct. Another rat given this latter series alternated regularly save that on the 3rd, 4th and 5th trials he went to the right hand box. In the regular series (on learning), there were more reversals and there was also a marked tendency to reverse after each success only.³ Inasmuch as this last type of behavior was not present when punishment and the end-stops were not used, it seems probable that these factors produced the behavior by modifying the simple alternation position habit.

The moral of these controls lies in pointing out the necessity of being on one's guard against complex position habits which otherwise might be taken as evidence of discriminative ability.

Many tests in comparative psychology which have been intended primarily as tests of discrimination have been vitiated because they have required the animal to *localize* the stimulus in order to give evidence of sensitivity. Hence when negative results are secured it is not known whether the animal was insensitive or whether it was simply unable to localize the stimulus. The method adopted in the present tests does not involve a localization factor (Johnson's work has this merit also).³ Hence the negative results secured when working with the pure tones 256 d.v. and 896 d.v. and with the chord 512 d.v. plus 640 d.v. are of great significance.

III

Learning Whistle—Tests were now begun on four untrained rats (Nos. 44, 45, 46 and 47) using as a stimulus 3906.17 d.v. on a Galton whistle. The whistle was held in clamps above the experiment box where the forks had been and was turned in such a manner that air currents were not directed downward upon the animals. It was sounded by blowing (with the experimenter's mouth) through a long tube. The standard intensity of this tone, when measured with a water manometer, was secured with a pressure of 16 cm. We may call this whistle,

³ Johnson, H. M. Audition and Habit Formation in the Dog. *Behav. Mon.*, vol. 2, no. 3 1913.

whistle A. Later during the control tests another Galton whistle was used, whistle B. B was a new instrument and was accepted as standard. Its tonal divisions were lower in pitch than those of A, so that 3413.3 on A was equaled by 3906.17 on B, using the same air pressure. (These measurements are very close approximations.) Pitches are always stated in terms of B.

In these tests the problem set the rat was the associating of a turn to the right for food with the whistle tone and a turn to the left for food with the absence of the whistle. 10 trials daily were given with punishment and reward. The period of learning plus the control period extended from April 17, 1914 to October 17, 1914.

Table 4 gives the results on learning. Rat 44 was dropped at the end of 650 trials because of an incurable habit of always going to the right whether the stimulus was sounded or not.

TABLE 4
NUMBER OF CORRECT REACTIONS IN EACH SUCCEEDING 50

Trials	Rats			
	44	45	46	47
50.....	23	21	19	19
100.....	18	26	21	25
150.....	28	24	13	22
200.....	28	32	19	25
250.....	29	25	14	21
300.....	28	21	32	28
350.....	28	26	27	23
400.....	28	24	33	24
450.....	29	32	35	23
500.....	27	27	26	29
550.....	27	29	28	22
600.....	32	32	33	39
650.....	10	35	34	29
700.....	..	35	40	37
750.....	..	43	28 of 30 trs.	37
800.....	..	39	..	42
850.....	..	41	..	39
900.....	..	36	..	39
950.....	..	46	..	43
960.....	..	10	..	9

The problem was considered learned by rat 46 at the end of 730 trials, and by rats 45 and 47 at the end of 960 trials. Controls were then instituted.

Controls—The following is a summary statement of the eleven controls used in analyzing the animals' reactions:

1. Leave off end-stops. Everything else normal.
2. Do not sound whistle. Everything else normal. Reactions correct if they fit the series.
3. Whistle is blown so as to give "rush of air sound" but no tone. The "rush of air sound" is probably twice as loud as it is when it accompanies the whistle tone. All else is normal.
4. Make "rush of air sound" with lips. Intensity equal to that of control 3. Care taken that air currents do not reach rats.
5. Clap hands in place of giving whistle tone. Medium intensity.
6. Two holes are bored in wall of room. A rubber tube passes through one from the experimenter to a Galton whistle placed in the adjoining room. The mouth of the whistle is set close in front of the second hole with a paper reflector directing the sound back into the experiment room. The whistle is set for the tone 3906.17 d.v. and is sounded in place of the whistle over the apparatus box. Everything else is normal.
7. Whistle over the apparatus box is used at the same intensity as the tone of control 6. The two were matched by sounding first one and then the other. The pressure in the water manometer was 4 cm.
8. Fork 1280 d.v. sounded in place of whistle and at a little more than the intensity of control 7.
9. The whistle over the apparatus box set at 1280 d.v. and sounded under normal conditions.
10. Fork 1152 d.v. and fork 1280 sounded as a chord in place of normal whistle tone. Slightly greater intensity than control 8.
11. The whistle used in control 6 was substituted for the whistle usually sounded over the box. The normal intensity and pitch were given.

Inasmuch as I regard the full presentation of the records on these controls as a matter of great importance, tables 5, 6 and 7 are given in the appendix. In these the reader will find a chronological statement of controls and results for each of the three rats. Here in the body of the paper, I shall gather together all of the tests made upon a given control irrespective of the relative times at which the tests were made.

Control 1.—When the alley-stops were not used the animals reacted normally.

Control 2.—All of the rats failed in their reactions when the whistle was not sounded. This demonstrates clearly that there was some cue involved in the presentation of the whistle stimulus that determined the reactions. A reference to table 6

Rat 45	20 trials	60% correct
Rat 46	40 trials	52% correct
Rat 47	20 trials	65% correct

(appendix) will reveal the fact that I have not included in No. 46's record 30 trials secured with this control during which 70% of the reactions were correct. This rat's dependence upon extra-auditory cues was very temporary. This is indicated by the fact that only 50% and 60% were made with control 6 just before and by the further fact that just succeeding the 70% with control 2 the rat fell back to 55% with the same control. I do not know what cue was used during that brief period.

Controls 3, 4 and 5.—All of the rats succeeded when the noise of rushing air was substituted for the whistle tone. One cannot argue from this that the rats did not hear the tone, although this is a possibility—in fact a probability when considered in connection with the other facts here brought together. Judging from this control alone or in connection with controls 4 and 5, an alternative hypothesis is evident, viz., the rats reacted to any auditory stimulus which stood out clearly at the moment of response. An inspection of table 7 (appendix) will

Control 3	Rat 45	40 trials	82% correct
	Rat 46	40 trials	82% correct
	Rat 47	70 trials	77% correct
Control 4	Rat 45	40 trials	80% correct
	Rat 46	30 trials	86% correct
	Rat 47	40 trials	77% correct
Control 5	Rat 45	20 trials	80% correct
	Rat 46	50 trials	80% correct
	Rat 47	50 trials	66% correct

indicate that rat 47 was disturbed slightly at the beginning of each series of tests with control 3. Each time, however, the disturbance quickly passed away. There was less disturbance with control 4. When control 5 was used, there was a complete breakdown at first; but later on in an isolated test period of 20 trials, 85% of correct reactions were made.

Rat 46 (table 6, appendix) was only disturbed with the 5th control, and this was speedily overcome—raised from 60% to 85%. Rat 45 was not disturbed by either of the three controls.

The net result of these controls is that the rats are able to respond correctly to two very different noises when these are given in the place of the standard whistle. So far, then, it is certain that although the rats were dependent in their reactions upon the auditory stimulus, this was certainly not of a specific nature. This is in harmony with the data set forth in the two companion papers (Hunter and Barber, above cited). It was necessary, therefore, to work further in order to show that the tonal element in the whistle was or was not effective.

Controls 6 and 7.—The only crucial test on the tonal element that could be made with the whistle depended upon ruling out any accompanying noise. There was only one method that was at all feasible. That was to remove the whistle to such a distance that distance itself would eliminate the extraneous factors. Such a test can only be suggestive and never conclusive: (1) It is impossible to tell whether or not the noise has been eliminated for the rat. (2) Distance not only cuts out the noise, but also cuts out overtones and lowers the general intensity of the stimulus. The first is the weighty objection. The second I believe has little or no weight because: (a) from the work on chords cited above and to be cited below (control 10), it is doubtful whether tonal complexity means much for the rat's reactions; and (b) control 7 indicates that the lowering of general intensity is non-effective. This point is made certain for pure tones, if not for klangs, by (work cited on pp. 219-220 of) the author's previous paper on the auditory sensitivity of the rat.

Control 6	Rat 45	50 trials	56%
Control 7	Rat 45	70 trials	78%
Control 6	Rat 46	90 trials	67%
Control 7	Rat 46	80 trials	81%
Control 6	Rat 47	50 trials	60%
Control 7	Rat 47	70 trials	71%

The numerical data just given indicate clearly that the rats broke down for control 6. We have just pointed out the possible reasons for such behavior,—the most probable one being the elimination of noise by distance. We must now indicate why

rats 45 and 46 were disturbed by control 7 where the normal whistle stimulus was simply sounded at a less intensity than usual. When the standard whistle is decreased in intensity the change is much the same as occurs when the whistle is taken to a distance, i. e., the noise accompanying the whistle is decreased in intensity if not eliminated and similar changes most probably occur among the overtones. Therefore, even from an a priori standpoint, one need not be surprised that the reactions with control 7 were of less than normal accuracy. The important fact is that they were significantly better than the reactions with control 6. Inasmuch as the stimuli in the two controls, were, for the experimenter, extremely similar in respect to intensity magnitude, it seems most probable that the rats were governed in their responses by the noise usually accompanying the whistle tone. There is no evidence that the animals heard the stimulus in control 6.

Controls 8 and 9.—In a previous experiment rats that had been trained to respond to the noise of handclapping were unable to make discriminative responses when tones were substituted for the standard stimulus, although the substitution of other noises was attended by positive results. The same facts appear here with the piston whistle tests. It will be seen from the

Control 8	Rat 45	70 trials	60% correct
Control 9	Rat 45	20 trials	90% correct
Control 8	Rat 46	70 trials	61% correct
Control 9	Rat 46	20 trials	85% correct
Control 8	Rat 47	80 trials	60% correct
Control 9	Rat 47	20 trials	85% correct

numerical summary here given that all of the rats failed unqualifiedly to respond in control 8 to the tuning fork 1280 d.v. Rat 46's percentage for control 8 would be only 54, if 20 trials were ruled out when the animal was responding to extra-auditory cues. (See above page 290, and appendix table 6.)

There was no tuning fork available whose vibration rate was at or above 2000 d.v. It was therefore impossible to use a fork of a pitch equal to the standard whistle. However, the next best thing was done. The whistle pitch was lowered in control 9 to the pitch of the fork used in control 8 (1280 d.v.). The data given above indicate that the rats reacted as well to this

whistle pitch as to the standard in spite of the fact that only failure attended the use of the tuning fork.

Control 10.—The difference in the results obtained in controls 8 and 9 may have been due to differences in the complexities of the stimuli. This is true although long tests were made (as described above) in a fruitless endeavour to set up a discriminative reaction to a common chord, 512 d.v. plus 640 d.v. In the present control the chord 1152 d.v. plus 1280 d.v. was sounded on forks in place of using the standard whistle. The animals again failed in their reactions. If, in spite of the fact that the results of my experiments indicate that differences in tonal complexity are not utilized, later studies should show that my tests did not offer complex enough klangs, they will be very interesting in establishing a threshold for tonal sensitivity on the basis of tonal complexity.

Rat 45	50 trials	66%
Rat 46	40 trials	57%
Rat 47	40 trials	57%

Control 11.—This control was introduced to supplement controls 6 and 7. In order to rule out the possibility that the data there obtained were due to intrinsic differences in the whistles, the one used in control 6 was placed over the apparatus in place of the standard whistle and was sounded at the intensity of control 7. Rat 47 was not tested, but the other two made 90% and above. It may be concluded from this that for the rat no intrinsic differences in the whistles were functionally effective.

IV

In instituting and continuing the series of tests with piston whistles as just set forth, the writer was influenced by two principle motives: (1) Uniform failure had waited upon all of the work with tuning forks. It was hoped that with the whistle positive data might be secured whose analysis would throw light upon the problem of tone sensitivity. (2) It has been suggested recently, notably by Yerkes, that where a difficult discrimination is required of an animal, training should first begin with a complex easily discriminable and gradually be directed toward the aspect upon whose presence the problem centers. When the present whistle tests had been begun pri-

marily with the first intention, it was thought advisable to extend them in the light of the second.

In the work published in volume 4 of this Journal, rats that had responded to noise by turning to the *left* were later given from 350 to 520 trials in an endeavour to force them to turn to the *right* for the tone 256 d.v. sounded on the fork. No one of the rats showed improvement during this interval.

In the present instance rats 45, 46 and 47 had been trained to react successfully to the whistle by turning to the right. They were then given a series of tests with the tuning fork 256 d.v. in an attempt to *train them to turn to the right for the fork tone also*. A new series of presentations was employed as follows:

rrlrrllrl Three hundred trials were given; but there was no
rrlrrllrlr improvement in the reactions from first to last. The
llrlrrllr following table is a summary of this fact. These re-
llrlrrllr sults lend further indirect confirmation to the con-
llrlrrllr clusion drawn above that the rats were depending upon noise

TABLE 5

Trials	Rats		
	45	46	47
50.....	25	28	27
100.....	26	32	28
150.....	29	28	28
200.....	29	28	27
250.....	25	23	27
300.....	27	31	31

in the whistle complex and not upon tone. The present results are also very striking when we compare them with the rat's ability to react to noises which are very dissimilar, from the experimenter's point of view, to those with which it has been trained. To quote from the previous paper, pages 221-222, "All of the tones given were for some reason very different from the noises. . . . Inasmuch as the animals reacted in the same manner to all of the noises, it is certainly a striking fact that none of the tonal stimuli given were classed as noises."

V

Retention Tests.—Forty-one days (for rats 46 and 47) and 45 days (for rat 45) after the tests on control 11 for rats 45 and

46 and on control 7 for rat 47, the animals were again tested on their ability to turn to the right for the whistle tone. During the interim, the work just described on the fork 256 d.v. was carried on. Whether this could have affected the retention will depend upon the rat's sensitivity to the tone in question. If he can hear the tone, there should at least be no decline in the accuracy of response due to the training on the fork. If, however, he cannot hear the tone, the training upon turning to the right for the fork will tend to break down the normal reaction of turning to the right for the whistle. The results show a decrease in accuracy of response for two rats. Rat 47 reacted normally. These results may be due either to the effect of time intervals or to habit interference.

Rat 45	Rat 46	Rat 47
Control 11, 90% of 20 trs.	Control 11, 100% of 20 trs.	Normal, 90% of 10 trs. Control 7, 80% of 10 trs.
Retention tests; per cent correct of 50 trials given		
72%	76%	80%

VI

The most significant data secured in the work upon the auditory capacity of the white rat may be summarized as follows, (data are here mentioned which were included in the author's previous paper and in Miss Barber's work.):

A. *Crucial Evidence Upon Tone Sensitivity:*

(1) The tone 256 d.v. sounded on the tuning fork was not discriminated: (a) by 6 untrained rats after 700 trials, (b) after 700 trials, by one rat that had learned to react to hand clapping within 400 trials; (c) after 350, 410 and 520 trials respectively by three rats that had been trained previously to respond to hand claps; (d) after 300 trials by 3 rats that had been trained to respond to a whistle.

(2) The tone 896 d.v. sounded on a tuning fork was not discriminated by 4 untrained rats after 700 trials.

(3) The chord 512 d.v. plus 640 d.v. sounded on forks was not discriminated; (a) by 2 untrained rats after 650 trials; and (b) after 650 trials by 2 rats that had been trained upon the

tone 896 d.v. If we count the difference between that tone and the present chord as sub-liminal, these 2 rats were given 1350 trials with no evidence of discrimination.

B. *Evidence Bearing Upon Tone Sensitivity Which While Not In Itself Crucial Is Yet Of The Greatest Significance:*

(1) Four rats trained to react to a whistle tone of 3906.17 d.v. would not react to a tuning fork chord (1152 d.v. plus 1280 d.v.), or to the fork 1280 d.v. when these were each substituted for the standard stimulus. When a whistle of the same pitch was sounded in an adjoining room so that distance probably eliminated the noise factor, the rats failed; although they made a significantly larger per cent of correct reactions when the standard stimulus was decreased in intensity to match the intensity of the distant whistle.

Further these same rats reacted properly when either of the following noises were substituted for the standard whistle; (a) the rush of air through the whistle; (b) sound of "rush of air" made with lips; and (c) clapping of hands. The rats reacted successfully to 1280 d.v. on the standard whistle *but failed when the same pitch* was sounded on a tuning fork.

(2) Three rats trained to react to hand clapping reacted successfully to the following noises when these were substituted: rattling of paper, dropping sunflower seed on tin, scratching on wood, drumming on the table with the fingers, rubbing two pieces of board together, hissing through the teeth, and rattling nails in a glass. These rats failed when the following tones were sounded in place of the hand claps: (a) 1024 d.v. on fork; (b) 256 d.v. on organ pipe sounded steadily; (c) b sounded in toots; (d) 1024 d.v. sounded steadily on organ pipe; (e) d sounded in toots; and (f) 341.3 d.v. on the organ pipe sounded steadily.

(3) Six untrained rats failed (after from 575-800 trials) to discriminate a very intense from a very faint sounding of the fork 256 d.v.

(4) Rats trained to localize a tapping noise ignored: the fork 256 d.v.; and the same pitch tooted upon an organ pipe. They responded to a noise made by tapping with the rubber end of a lead pencil upon the resonator box of the fork 256 d.v. This gave an interrupted noise of the same predominant pitch as the fork.

CONCLUSIONS

(1) There is a practical insensitivity to many pitches in the lower region of the scale for the white rat. This apparently goes along with a sensitivity to noises of the same predominant pitch.

(2) Differences in tonal complexity and intensity may be considerable without making discrimination possible.

(3) Apparent reactions to tone are most probably made to accompanying noises.

(4) If, after all, there is a sensitivity to tonal stimuli as here tested, then, for the rat, tones and noises are very different classes of stimuli.

APPENDIX

Chronological statement of controls used with rats in whistle tests.

TABLE 5

RAT 45

Nature of test	Trials	Per cent correct
Con. 1.....	10	90
Con. 2.....	20	60
Normal.....	20	90
Con. 3.....	20	80
Normal.....	10	100
Con. 4.....	20	80
Normal.....	60	83
Con. 6.....	10	60
Con. 7.....	20	85
Normal.....	10	100
Con. 6.....	10	60
Con. 8.....	10	50
Con. 7.....	10	80
Con. 8.....	10	50
Con. 6.....	10	50
Normal.....	30	83
Con. 9.....	10	90
Con. 8.....	20	70
Con. 10.....	50	66
Normal.....	20	95
Con. 8.....	20	60
Con. 3.....	20	85
Con. 4.....	20	80
Con. 5.....	20	80
Con. 6.....	20	55
Con. 7.....	40	75
Con. 11.....	20	90

TABLE 6

RAT 46

Nature of test	Trials	Per cent correct
Con. 1.....	20	90
Con. 2.....	10	50
Normal.....	40	77
Con. 2.....	10	50
Con. 1.....	10	80
Con. 3.....	10	70
Normal.....	70	63
	last 40	100
Con. 3.....	10	100
Con. 4.....	10	100
Con. 5.....	10	60
Normal.....	30	90
Con. 5.....	20	85
Con. 6.....	10	60
Con. 7.....	10	50
Normal.....	10	100
Con. 6.....	20	75
Con. 7.....	20	85
Con. 6.....	10	50
Con. 7.....	10	80
Con. 6.....	10	60
Con. 7.....	10	100
Con. 8.....	20	80*
Con. 2.....	10	100*
Con. 2.....	20	70*
Normal.....	10	80*
Con. 2.....	20	55*
Con. 8.....	10	60
Con. 8.....	20	50
Normal.....	20	90
Con. 9.....	20	85
Con. 10.....	40	57
Normal.....	20	95
Con. 8.....	20	55
Con. 3.....	20	80
Con. 4.....	20	80
Con. 5.....	20	85
Con. 6.....	40	72
Con. 7.....	30	83
Con. 11.....	20	100

* For comments upon these controls see body of text.

TABLE 7

RAT 47

Nature of test	Trials	Per cent correct
Con. 1.....	10	80
Con. 2.....	20	65
Normal.....	20	90
Con. 3.....	20	60
Con. 3.....	20	95
Normal.....	10	90
Con. 4.....	10	60
Con. 4.....	20	85
Con. 6.....	10	60
Con. 7.....	10	50
Con. 6.....	10	60
Con. 7.....	10	50
Normal.....	20	80
Con. 7.....	10	60
Con. 5.....	10	50
Con. 5.....	20	55
Normal.....	20	85
Con. 9.....	10	90
Con. 8.....	10	60
Con. 9.....	10	80
Con. 8.....	10	60
Con. 10.....	20	60
Con. 8.....	10	50
Normal.....	20	80
Con. 10.....	20	55
Con. 8.....	50	62
Con. 3.....	10	76
Con. 3.....	20	85
Con. 4.....	10	80
Con. 5.....	20	85
Con. 6.....	30	60
Con. 7.....	20	100
Normal.....	20	95
Con. 7.....	10	60
Normal.....	10	50
Normal.....	10	90
Con. 7.....	10	80

THE RELATION OF STRENGTH OF STIMULUS TO RAPIDITY OF HABIT-FORMATION IN THE KITTEN

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For this study of the relation of strength of stimulus to rapidity of learning I have used the method which Yerkes and I found satisfactory in our similar study of the dancing mouse.¹ But instead of requiring the kitten to choose between white and black, as in the case of the mouse, I required it to discriminate between light and dark—that is the kitten had to choose in the light-dark series instead of the white-black series. Irrespective of the relative positions of the two boxes the subject had to choose the light one. Should the kitten enter the dark box it received an electric shock, and was never allowed to escape by passing through the same.

The apparatus was very much the same as that used with the dancer (for general construction see figures 1 and 2, page 460, of the article referred to above). The experiment box was divided into a nest box, an entrance chamber and two electric boxes. The entrances and exits to the electric boxes were 9 by 9 cm. each. The electric boxes were placed in the circuit of a constant electric current. In this circuit was a double key by which the experimenter could direct the current through either box he might wish. The inductorium and resistance coil were placed in an adjoining room thus eliminating all the noise of the constant buzz of the inductorium. The current was furnished by a storage battery which was kept constant at a voltage of 19.5 and amperage of 4. To govern the amount of light entering the electric boxes, the entire end of the experiment box containing the electric boxes was covered, and two openings cut in the cover, one directly over each electric box. In order to prevent the kitten from seeing the opening in this cover as it entered the electric box, a platform 25 cm. wide was placed 12 cm. from the top of the box and directly

¹ *Jour. of Comp. Neurol. and Psy.*, 1908, **18**, 459-482.

over the wires. The experimenter determined which electric box should be light and which should be dark by placing a cover over one of the openings. The cardboard cover was shifted in the same order as in the experiment with the dancer (table 1, page 461).

The kitten was placed in the nest box by the experimenter and a plain glass cover put over the box to prevent the kitten's climbing out at the top. The only way left for the animal to escape was to pass through an opening into the entrance chamber and thence through the electric box and out at an exit at the rear of the experiment box. A mirror was placed so that the experimenter could see the kitten without the kitten's seeing the experimenter. The play instinct caused the kitten to be very restless and, thus, it soon attempted to make its escape. If it chose the light box it was allowed to pass through undisturbed; but should it choose the dark one it received an electric shock. This shock usually caused a hasty retreat, but should the animal attempt to pass on over the wires the experimenter forced it to return into the entrance chamber not allowing it to escape through the dark box.

Each of the 18 kittens used was given ten tests each day until it succeeded in choosing the light box correctly for three consecutive days. If the kitten should enter far enough into the dark box to receive a shock it was recorded as a mistake but in order for the trial to be counted a test the kitten must escape from the box. The principal motives for the kitten's escape were the instinct of play and the gregarious instinct. The animals were given their usual meals during the day, but I always fed them at the close of the experiment.

Each kitten was just six weeks old when I began to train it. All were of the same stock of cats. I conducted three sets of experiments. First set was done with the condition of visual discrimination rather difficult, using a medium and relatively strong stimuli. For the second set the condition of discrimination was less difficult. For the third set the condition of visual discrimination was fairly easy.

At the beginning of the training of a set of kittens I allowed each one to pass through the electric boxes a number of times without turning the electric current in either box. This was to teach the kitten that there was a way out of the box and also

to tend to establish in the animal the habit of escaping. During this preliminary work I shifted the cardboard from side to side to determine whether or not the kitten had any preference for the light or dark box and found no preference shown.

The difference in the amount of light entering the two electric boxes was that which would pass through an opening in the cover 23.5 by 13 cm. Of this opening 16 by 13 cm. was over the platform which was 12 cm. below the top of the box. For the medium stimulus a current with a voltage of 19.5 and an amperage of 2.5 was run through an inductorium with a coil set 3.6 cm. from the closed end. For the strong stimulus a current was used with the voltage and the inductorium the same as for the medium stimulus but the amperage was 3.5.

Results of experiments of set 1. Tables 1 and 2 show detailed results of set 1. At the top of each table are given the numbers of the kittens which were used under the conditions named in the heading of the table. The first column gives the number series; the other columns give the number of errors and the average of errors made by male and female and also the general average; while the last line gives the total number of trials and their average for perfecting the habit.

TABLE 1
THE RESULTS OF EXPERIMENTS OF SET I, MEDIUM STIMULUS
(VOLT. 19.5, AMP. 2.5)

Series	Males			Females			General Average
	No. 1	No. 5	Average	No. 2	No. 6	Average	
1.....	6	4	5	7	4	5.5	5.25
2.....	2	2	2	2	3	2.5	2.25
3.....	4	2	3	6	4	5	4
4.....	4	2	3	4	3	3.5	3.25
5.....	1	3	2	1	2	1.5	1.75
6.....	0	4	2	1	2	1.5	1.75
7.....	1	1	1	0	2	1	1
8.....	1	1	1	1	2	1.5	1.25
9.....	0	0	0	0	3	1.5	0.75
10.....	0	0	0	0	0	0	0
11.....	0	0	0	0	0	0	0
12.....					0	0	0
Total No. of trials....	80	80	80	80	90	85	82.5

TABLE 2
THE RESULTS OF EXPERIMENTS OF SET I, STRONG STIMULUS
(VOLT. 19.5, AMP. 3.5)

Series	Males			Females			General Average
	No. 3	No. 7	Average	No. 4	No. 8	Average	
1.....	6	4	5	5	4	4.5	4.75
2.....	5	3	4	4	4	4	4
3.....	2	3	2.5	4	4	4	3.25
4.....	4	3	3.5	4	2	3	3.25
5.....	7	2	4.5	2	3	2.5	3.5
6.....	3	2	2.5	3	4	3.5	3
7.....	2	2	2	2	4	3	2.5
8.....	1	2	1.5	1	4	2.5	2
9.....	0	4	2	1	3	2	2
10.....	2	1	1.5	0	1	0.5	1
11.....	0	0	0	0	3	1.5	0.75
12.....	0	2	1	0	2	1	1
13.....	0	0	0		0	0	0
14.....		0	0		0	0	0
15.....		0	0		0	0	0
Total No. of trials....	100	120	110	90	120	105	107.5

Special conditions of set 11. The visual discrimination was made less difficult by putting a cover over 15 by 40 cm. of the nest box and by cutting out the openings over the electric boxes until they were 36 by 13 cm. instead of 23.5 by 13 cm. The strengths of stimuli were the same as in set 1, but only two kittens were used for each strength.

TABLE 3
THE RESULTS OF EXPERIMENTS OF SET II, MEDIUM STIMULUS
(VOLT. 19.5, AMP. 2.5)

Series	Male, No. 9	Female, No. 10	Average
1.....	5	5	5
2.....	4	5	4.5
3.....	4	2	3
4.....	3	2	2.5
5.....	2	1	1.5
6.....	1	1	1
7.....	0	0	0
8.....	0	0	0
9.....	0	0	0
Total number of trials.....	60	60	60

TABLE 4

RESULTS OF EXPERIMENTS OF SET II, STRONG STIMULUS

(VOLT. 19.5, AMP. 3.5)

Series	Male, No. 11	Female, No. 12	Average
1.....	4	6	5
2.....	4	2	3
3.....	3	4	3.5
4.....	3	2	2.5
5.....	3	1	2
6.....	2	0	1
7.....	0	0	0
8.....	0	0	0
9.....	0		0
Total number of tests.....	60	50	55

Special conditions of set III. The nest box and entrance chamber were lined with black cardboard and the electric boxes were lined with white. The openings over the electric boxes were cut out till they were 40 by 18 cm. and the nest box and entrance chamber were covered with cardboard all but an opening 20 by 40 cm. Thus the condition of visual discrimination was made fairly easy. The stimuli used were the same as in the previous experiments, but with one additional stimulus.

TABLE 5

RESULTS OF EXPERIMENTS SET III, STIMULUS WEAK (VOLT 19.5, AMP. 1.5)

Series	Male, No. 13	Female, No. 14	Average
1.....	5	6	5.5
2.....	5	4	4.5
3.....	4	4	4
4.....	3	2	2.5
5.....	2	3	2.5
6.....	3	2	2.5
7.....	1	1	1
8.....	1	0	0.5
9.....	0	0	0
10.....	0	0	0
11.....	0		0
Total number of trials.....	80	70	75

TABLE 6
RESULTS OF EXPERIMENTS OF SET III, STIMULUS MEDIUM
(VOLT. 19.5, AMP. 2.5)

Series	Male, No. 15	Female, No. 16	Average
1.....	4	6	5
2.....	5	4	4.5
3.....	4	4	3.5
4.....	4	2	3
5.....	3	2	2.5
6.....	0	0	0
7.....	0	0	0
8.....	0	0	0
Total number of trials.....	50	50	50

TABLE 7
RESULTS OF EXPERIMENTS OF SET III, STIMULUS STRONG
(VOLT. 19.5, AMP. 3.5)

Series	Male, No. 17	Female, No. 18	Average
1.....	5	4	4.5
2.....	4	3	3.5
3.....	1	1	1
4.....	0	1	0.5
5.....	0	0	0
6.....	0	0	0
7.....	0	0	0
Total number of trials.....	30	40	35

Possibly no one realizes more fully than the experimenter certain crudities of method in this experiment, but still there are some things of interest to the animal psychologist. And if any conclusions may be drawn from the use of so few animals those conclusions are in accord with previous findings in the dancer.

Conclusions. 1. The rapidity with which kittens acquire the habit of always choosing the light box may be seen from the following results: Under fairly difficult conditions of learning, with a medium stimulus it took on the average 82.5 trials for the kitten to perfect a correct habit, and with a strong stimulus 107.5 trials; under less difficult conditions it took 60 trials with a medium stimulus, and 55 trials with a strong stimulus; and under fairly easy conditions it took 75 trials with a weak stim-

ulus, 50 trials with a medium stimulus, and 35 trials with a strong stimulus.

2. The relation of the painfulness of the electrical stimulus to the rapidity of habit formation depends upon the difficultness of the visual discrimination.

3. When the discrimination is difficult the medium strength of stimulus was found to be the more favorable to habit formation; but when the discrimination is less difficult the difference between the unpleasant and the very unpleasant stimuli is not marked. When the discrimination is easy the rapidity of habit formation increases as the unpleasantness of the stimuli is made greater, at least within certain limits.

NOTES

THE MATING OF *LASIUS NIGER* L.

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It was three o'clock on the afternoon of September the seventeenth, 1913. For two days we had been having frequent showers; even then, although the sun was shining brightly, there were numerous clouds in the sky, any one of which, without a moment's notice, might float before the sun. The temperature was only 78 degrees Fahrenheit; but, compared with the 73 degrees of the afternoon of the sixteenth and with the 63 degrees of the afternoon of the fifteenth, it seemed quite warm. The numerous nests of the ant *Lasius Niger* L., which had long existed, unnoticed, beneath the pavements and in the vacant lots of St. Louis, had suddenly been rendered conspicuous by the restless myriads of gigantic virgin females, miniature males, and small workers that were swarming from them and forming agitated masses of ants about each entrance.

On viewing this periodically repeated phenomenon one is tempted to assume that the ants have suddenly become negatively geotactic and positively phototactic; and this hypothesis is strengthened by the fact that, on the evenings following such an occasion, females of the species may be captured at the street lights. It may have been a negative geotropism, it certainly was not a positive phototropism which urged the ants from the nest; for the sunlight does not penetrate into the nests. A prolonged and careful observation of the virgin females and neuters of a nest situated at the foot of a large grape-vine revealed conditions that do not harmonize with so simple an explanation. If the behavior of these ants were wholly a negative geotropism, or a positive phototropism, or a combination of both, then they should have climbed ever upward until the tips of the twigs were reached; but, that is not the way they behaved. Along the lower four feet of that vine the females

and neuters were constantly ascending and descending. To watch the agitated promenading of these restless ants up and down the stem, was to be convinced that these activities of the unmated females and of the neuters were not merely a tropism. Evidently the physiological changes caused by the maturing of the sexual powers had initiated a restless meandering.

I am not certain how the behavior of the males should be interpreted. The leaves of the grapevine and the tops of other uprights were black with them. The stem of the vine supported countless numbers of them; but my attention was so completely concentrated upon the movements of the females and neuters that I did not notice whether the males were moving ever upwards or to and fro.

The concentration of attention upon the virgin females was for the purpose of observing every detail of their mating behavior. Several females were watched from the time they left the nest until they flew away. Both on the ground and on the grapevine, they roamed in and out among the males, jostling them to the right and to the left, without stimulating the least response. One is warranted, then, in concluding, with previous writers, that the mating of this species does not occur, normally, either on the ground or on some support.

While watching the females promenade to and fro upon the grapevine, numerous males and a few females flew away from the nest. When I had fully satisfied myself that mating occurred neither on the ground nor on a support, I arose and looked about me. For fifteen to twenty feet above the ground, the air was thick with the minute, gnat-like, males of this species. Not only the atmosphere above my yard, but that above all of the yards of the vicinity was alive with these miniature creatures, for the males of all of the *Lasius* nests of the city were having an aerial dance. They rose and fell, swerved to first one side and then to the other, occasionally they alighted on the ground, and, after a short rest, unless captured by the foraging ants of another genera, arose and repeated over and over again the maneuvers—thus they performed the prenuptial dance of the species, and all of the participants were males.

From time to time lone virgin females appeared in the midst of the dancing bachelors. Starting near the ground, such a female would corkscrew upwards, sometimes vertically, some-

times obliquely, and disappear above the two-story houses. Some of these females caused no disturbance of the dance; others attracted towards them one or more of the participants which accompanied them beyond the range of human eyes. Somewhere in the air mating would occur and the female, no longer a virgin, would return to earth. I did not have the pleasure of observing a pair at the moment of copulation; but I captured several of the brides as they descended; each with her miniature husband attached, appendage like, to the tip of her abdomen.

The altered appearance caused by the clinging of the male, made it easy to recognize a newly mated female afar off. Several were followed until they settled on the plants of my garden. After alighting and before the male had detached himself, the female, by means of vigorous strokes of her third pair of legs, would break off the wings of first one side and then of the other. These wings were for the honey-moon flight; since the females of this species mate but once in a life time, they were cast aside as useless encumbrances. Those wings were badges of virginity; now that she had become a matron, she discarded those emblems of maidenhood.

What a feast these marriage festivities furnished the insect-feeding ants of the community! Around the outskirts of each band of excited ants, *Formica* scouts were capturing the male stragglers and dragging them alive to their nests. All over the ground beneath the dancing males, active foragers of these same species of *Formica* were capturing such ants as happened to fall to the earth. Even the large females became prey of these alert ants. Often two and even three ants were observed dragging off the same female.

At the beginning of these observations, the sun was shining brightly; later the clouds became so thick that not a ray of sunlight could reach the earth. The prenuptial dance and the mating continued, in both sunshine and shadow, until about the close of day. Then the dancers gradually vanished until all that remained of the countless multitudes were a few straggling males and an occasional female. Even after the last of these males had disappeared, an occasional lone female would corkscrew upwards through the air. Poor belated virgins! Too late to perform the mission of their sex! Some, if not all, haunt-

ed the street lights of the city for a night or two; but the opportunity to become mothers had passed forever. The wedding festivities of *Lasius niger* had closed for the season. No new festivities could be inaugurated until, in some way not understood, the physiological and meteorological factors had stimulated a future generation of ant maidens and ant bachelors to wed.